WindScanner.dk - a new Remote Sensing based Measurement Infrastructure for On- and Offshore Wind Energy Research

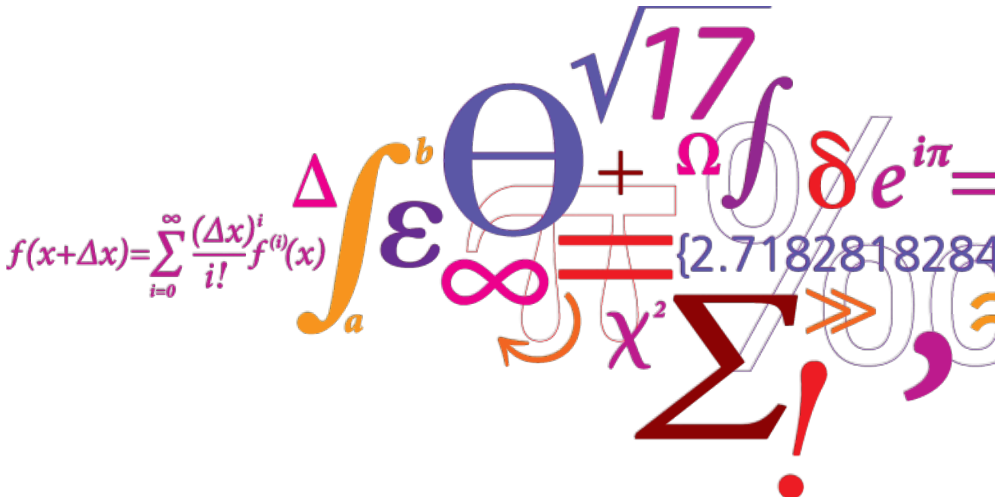
Mikkelsen, Torben

Publication date:
2013

WindScanner.dk

- a new Remote Sensing based

Measurement Infrastructure
for
On- and Offshore Wind Energy Research



Torben Mikkelsen

Danish Wind Power Research 2013
Danish Research Consortium for Wind Energy
Trinity GI. Færgevej 30, Fredericia
May 27-28, 2013

DTU Wind Energy
Department of Wind Energy

WindScanner.eu

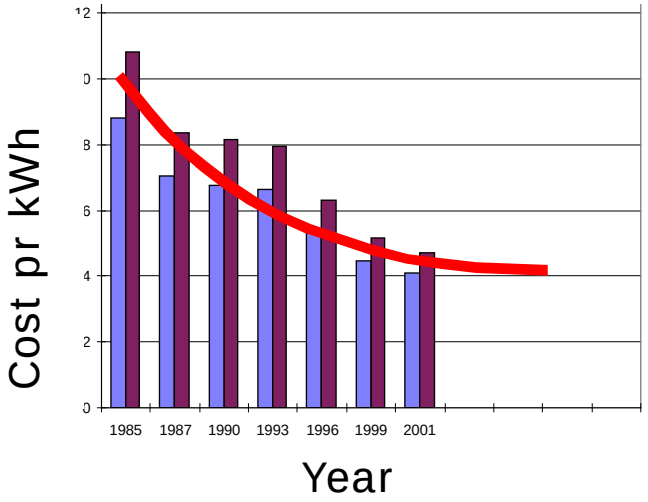
... In 2002 Risø opens the test station for large wind turbines @ Høvsøre ...:

5 test stands
Max. 10 MW
Max. height 165 m

Small test turbines at Risø - 1979

Østerild Prototype Wind Turbine Test Centre 2011: +7 stands @ 250 m tall WT's …

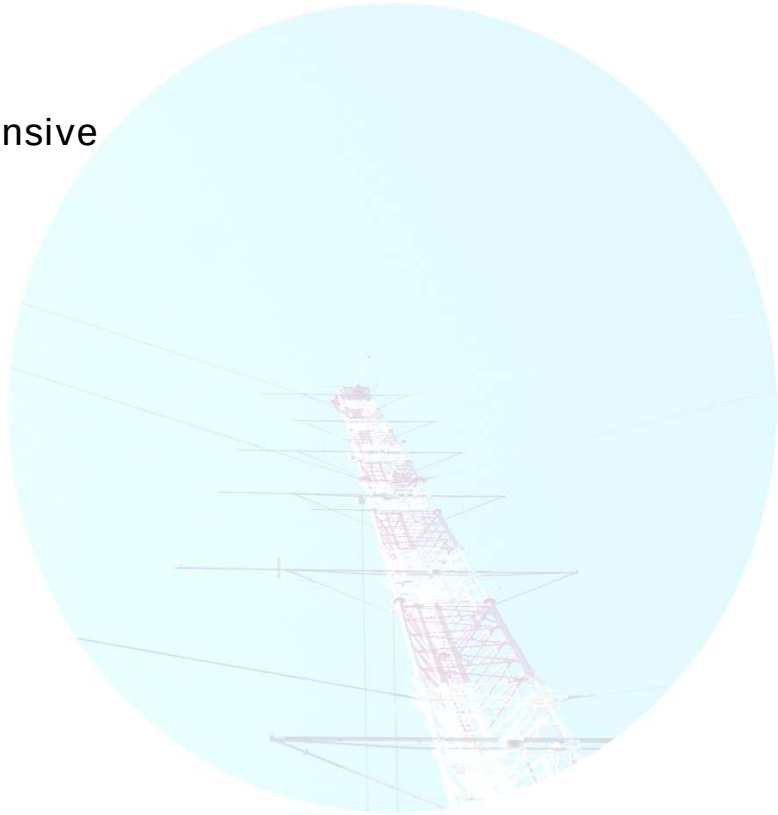
… Wind Turbines are getting bigger and bigger …



Remote Sensing (RS) of Wind Speed:

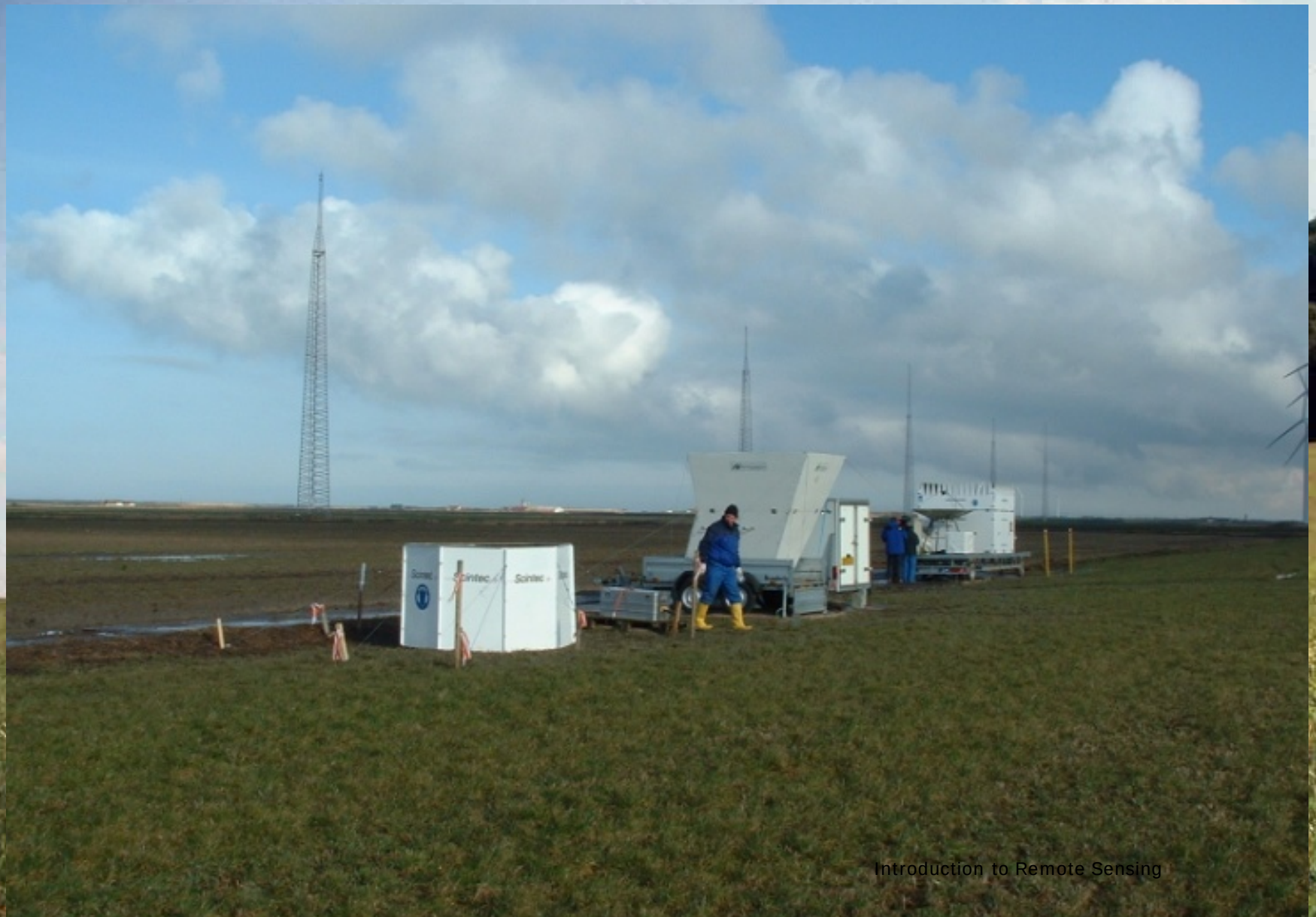
Why ”Remote Sensing” ?

- Wind Turbines are becoming BIG!
- Tall (> 100 meters) Meteorological Towers expensive
- Tall Met Towers are difficult to move



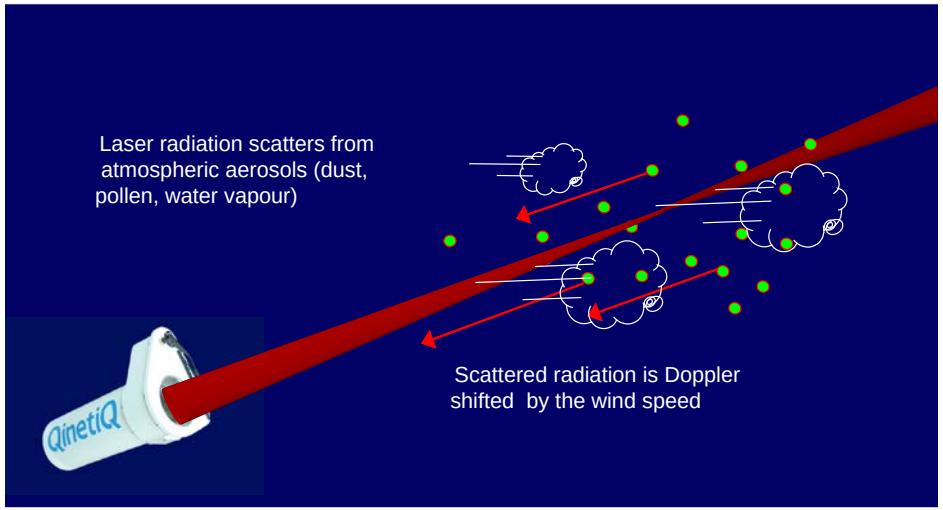
Monostatic SODAR

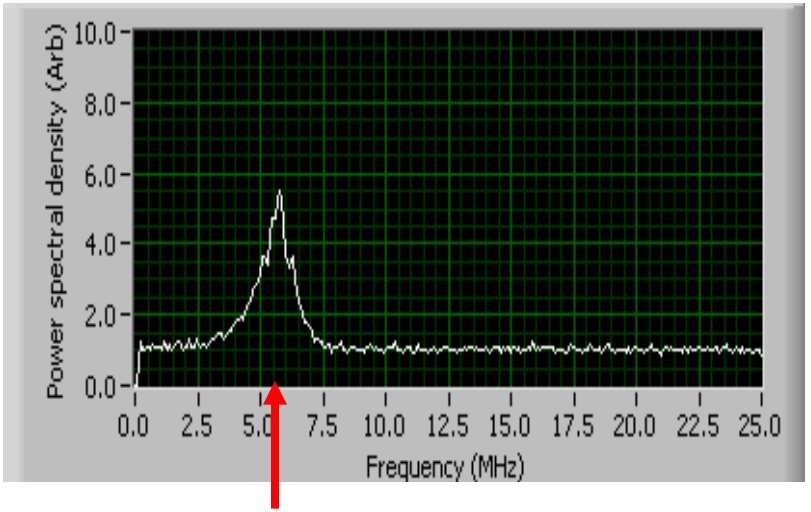
Ground-based RS Wind Sensors @ Høvsøre 2004



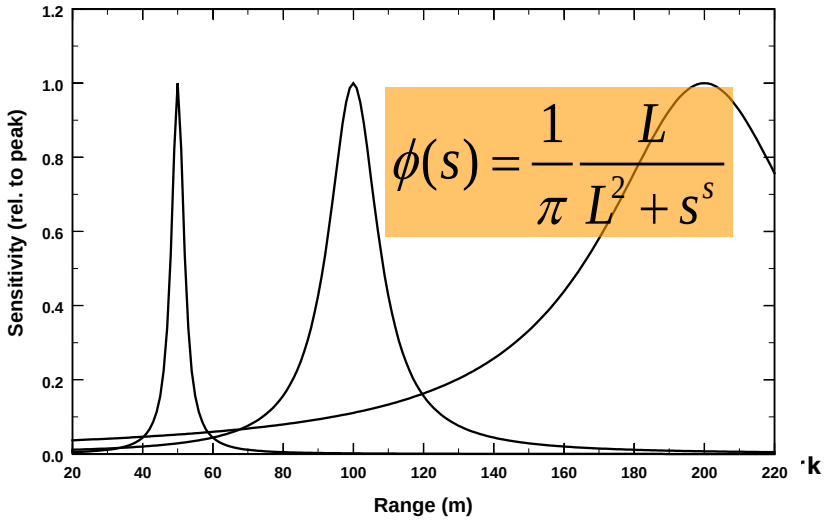
2003 : New Telecom comp. fibre wind Lidars

Principles of the Doppler LIDAR





$$peak = \frac{\int f\,P(f)\,df}{\int P(f)\,df}$$

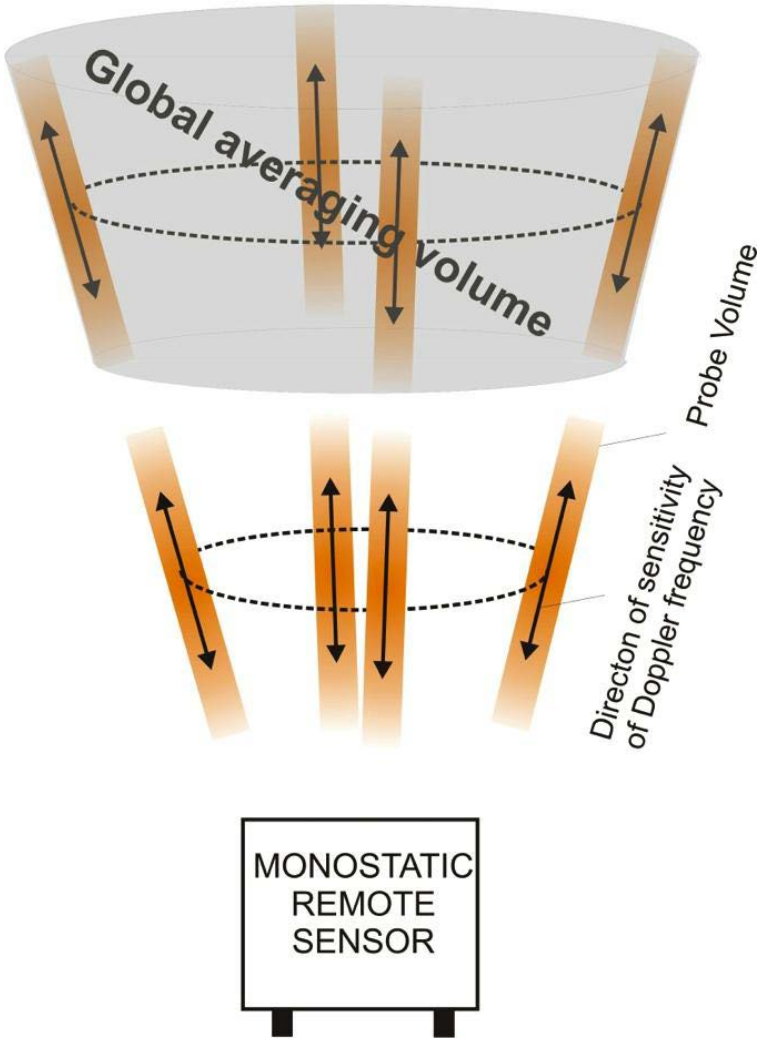


$$\phi(s) = \frac{1}{\pi}\frac{L}{L^2 + s^s}$$

Altitude	L
40m	2.5 m
60m	6 m
100m	16 m
200m	65 m

Pulsed and Continuous wave Lidars:

Velocity Azimuth Display VAD Scanning Mode:



Ground-based RS Wind Sensors @ Høvsøre 2003 => 2012:

SODARS
(2004)

CW LIDARS
(2006-)

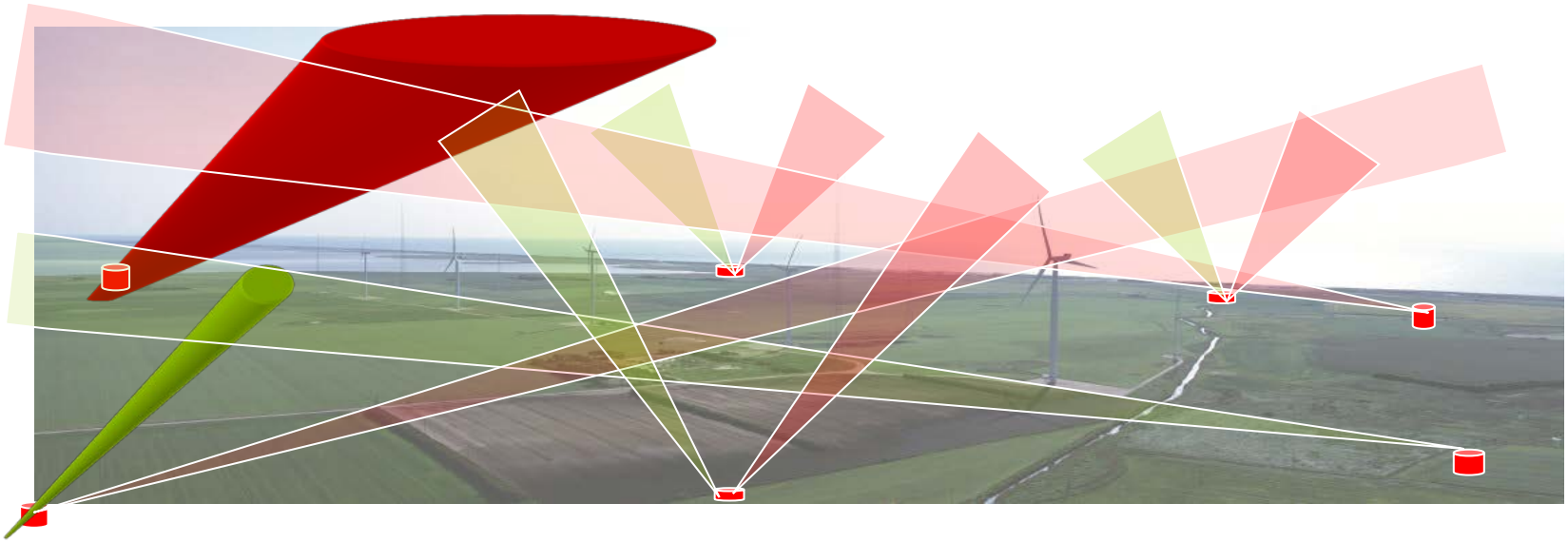
Pulsed LIDARS
(2007-)

Remote Sensing for Wind Energy:

Measurements of Wind Velocity in 3D Space and Time

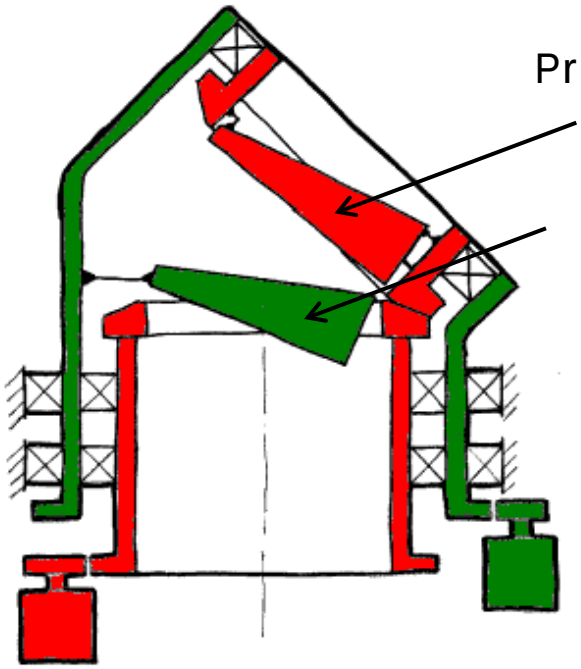
High Signal/Noise (range)

High Temporal and Spatial Resolution (fast scanning-small measurement volumes)

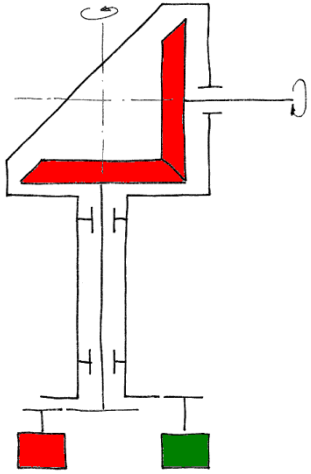


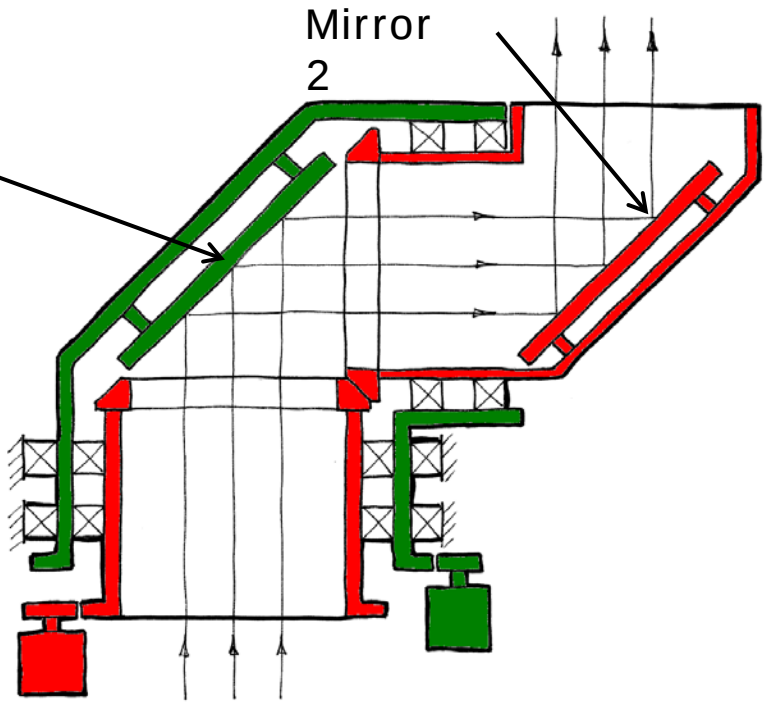
Risø DTU
National Laboratory for Sustainable Energy

Basic mechanical principles used in WindScanner.dk



Laser beam controlled by two rotating prisms





Laser beam controlled by two rotating mirrors

Both systems are based on two motors and a coupled gear system. That gives full control of the direction of the beam.

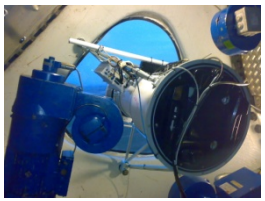
The WindScanner RI's evolution:

From new Wind Lidar Technology towards new Wind Energy Research Infrastructures…:

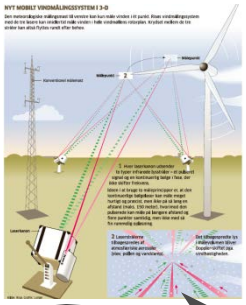
First CW Wind lidar 2004

MusketeerEX 2007/2008

SpinnerEX 2009



WindScanner. dk2010-2013



Current Status

EU ESFRI Road Map 2010 ff

RI focus

Scientific focus

Technical focus

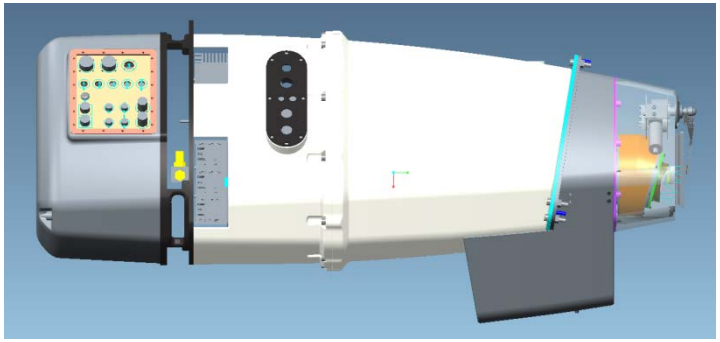
WindScanner.dk

EWEA 2012

WindScanner.dk Research & Innovation Product overview (2013)

This document contains descriptions of Wind Scanner equipment developed by DTU Wind Energy and IPU in the period 2007 to 2013.

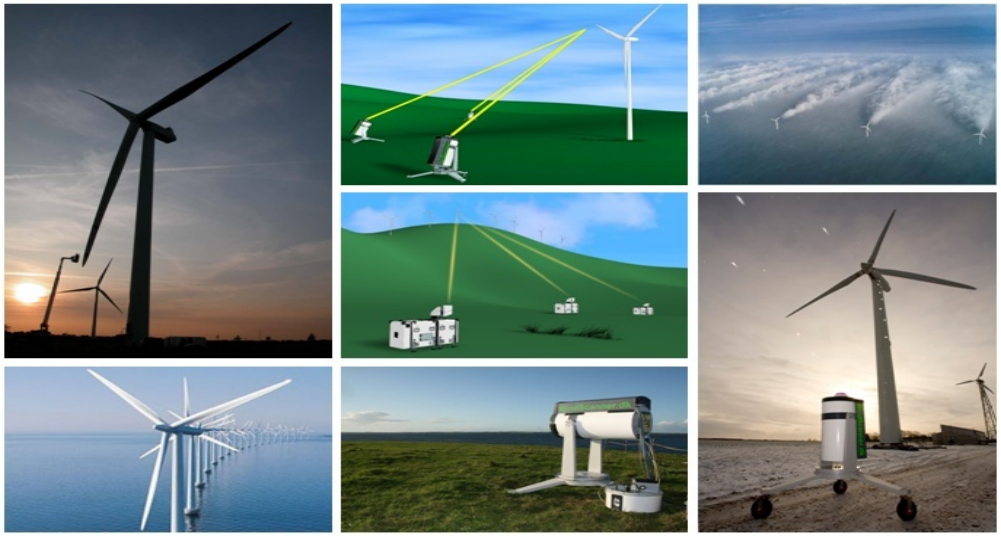
The main purpose with this document is to transfer information about the equipment to
the Windscanner.eu partners.

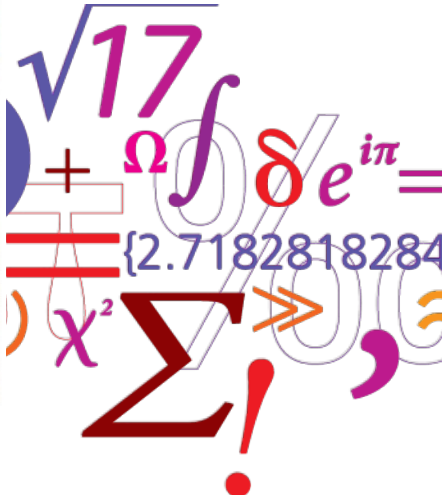


Steen Andreasen. January 2013.
www.ipu.dk

WindScanner.eu PP 2012- 2015

The European WindScanner Facility – Center for Wind Energy and Turbulence Research





EERA Partners:
DTU SINTEF FORWIND Fraunhofer IWES; CRES; CENER; LNEG; UoP

DTU Wind Energy
Department of Wind Energy

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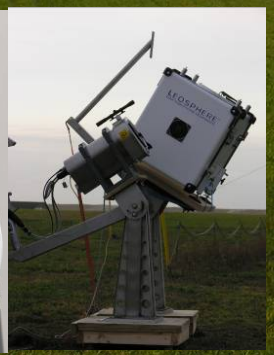
Experimental Progress: Høvsøre Dec. 2 - 7 2007



Wind Scanner

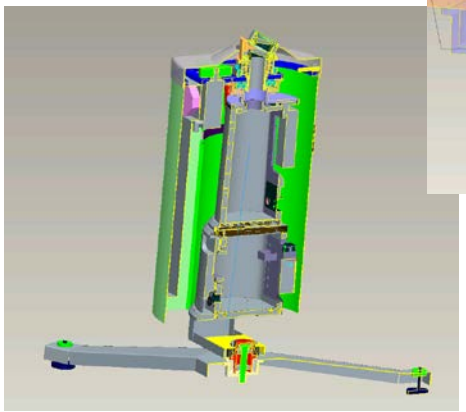
MusketeerEx-II:

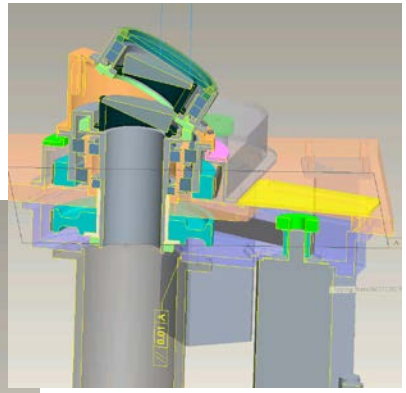
Høvsøre Dec. 2008 Windscanner lidar test

Spatial-resolution improved ”Stretch Pod” Unit 107 (left) vs. Windscanner Unit 120 (right)

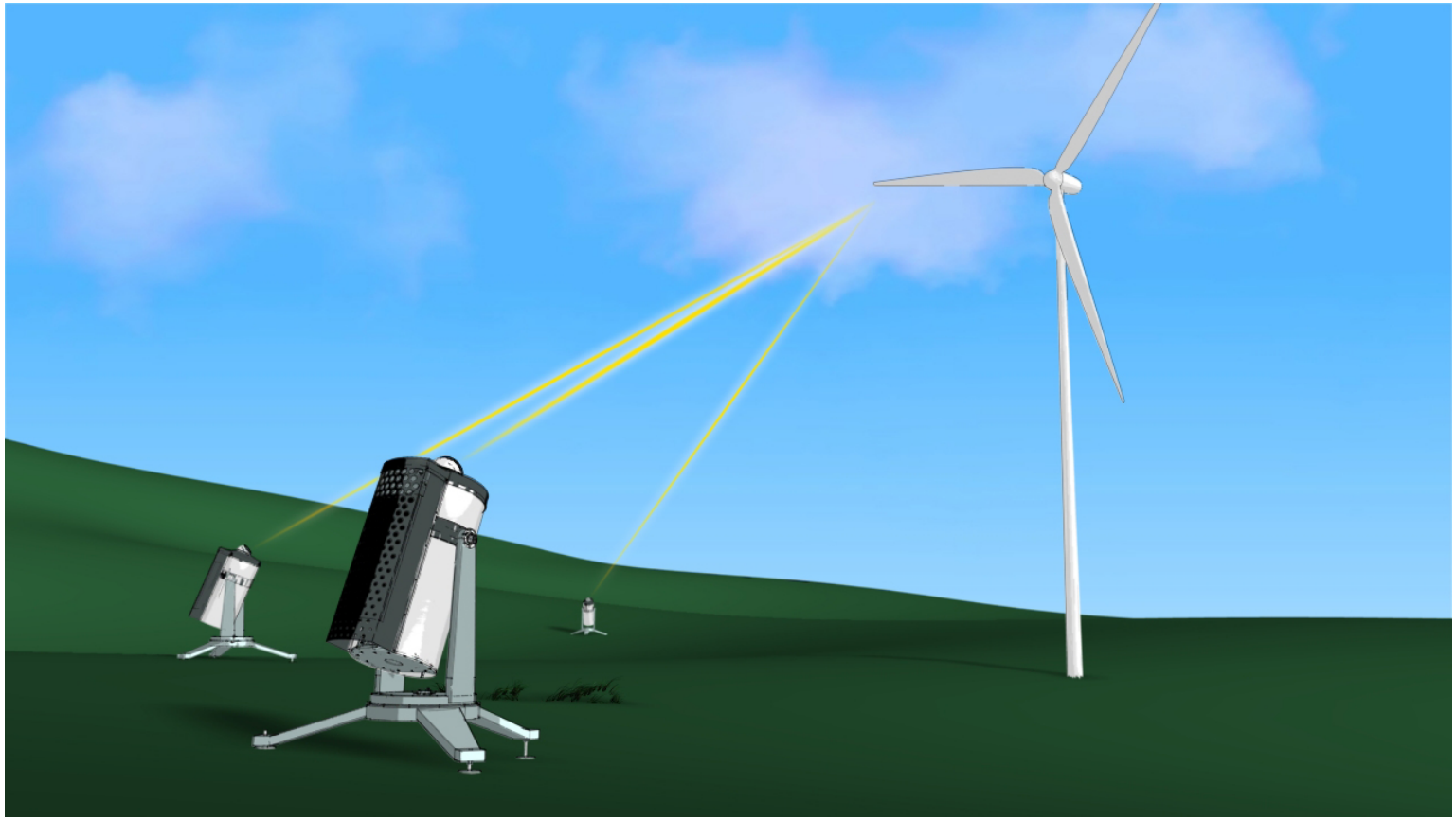
WindScanner.dk: 12 -axes Control System

Conneting and steering of 9 (+3) akser:





Short-range WindScanners (cw)

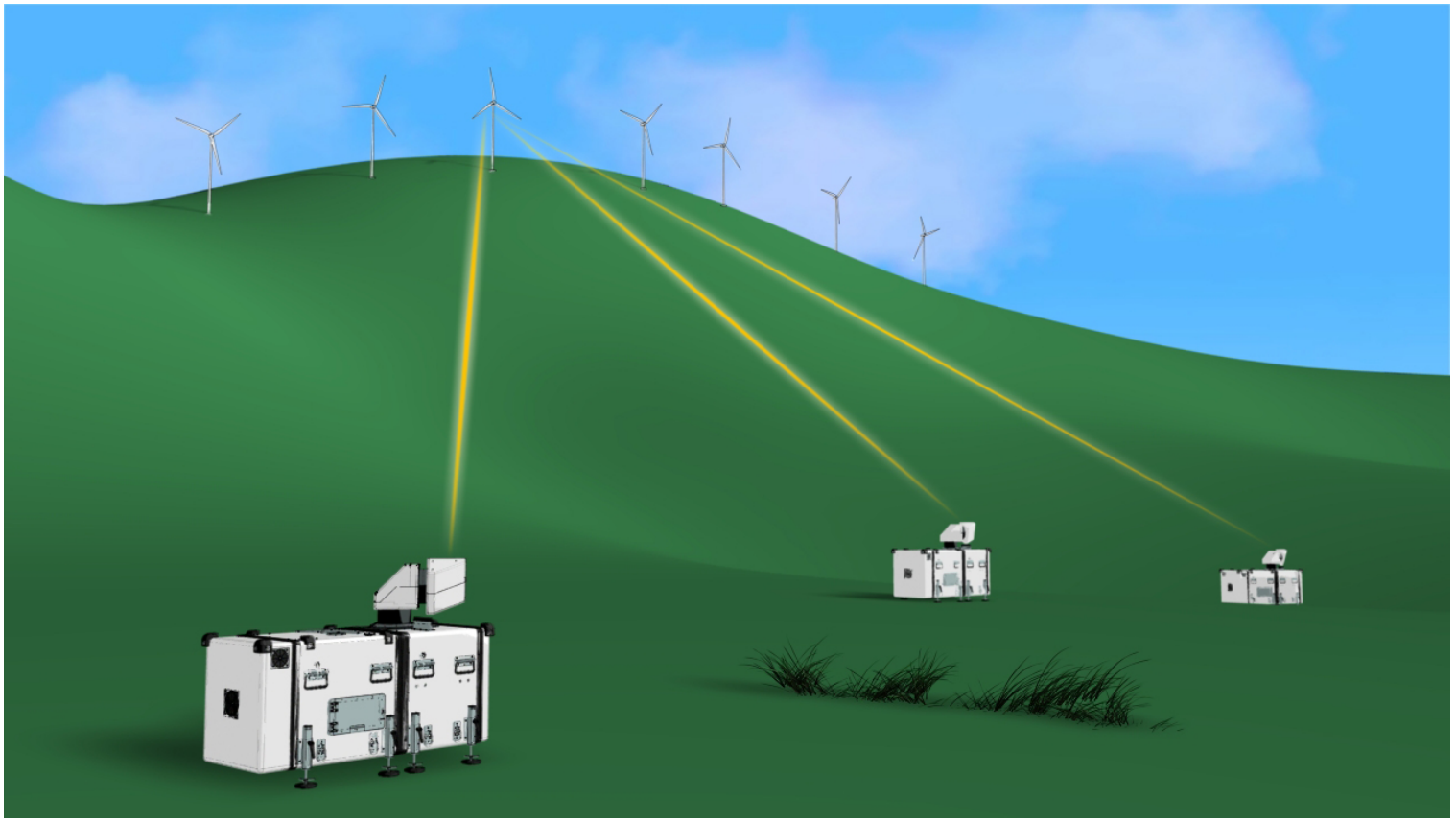


WINDSCANNER OVERVIEW

Preparing for field measurements (3 X Short-range WindScanners)

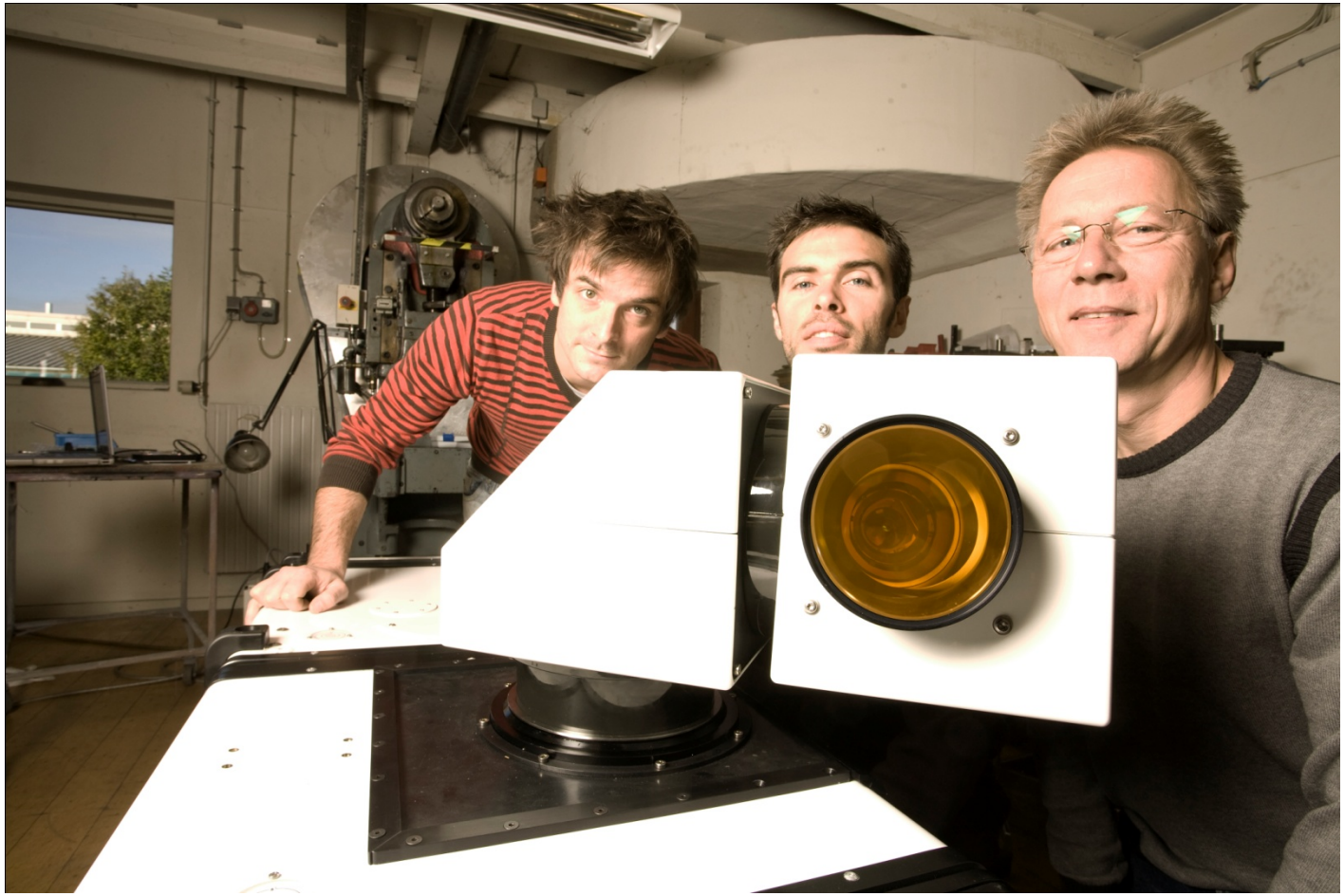
Long-Range WindScaners (pulsed)

On and offshore Ressource Assessment, Wind Conditions, Wakes



Long-range WindScanner Oct 2010
Range 5 (10) km => New Leosphere product WLS200S

Risø DTU Workshop w/ Leosphere, Fr. and IPU



Marking GPS positions

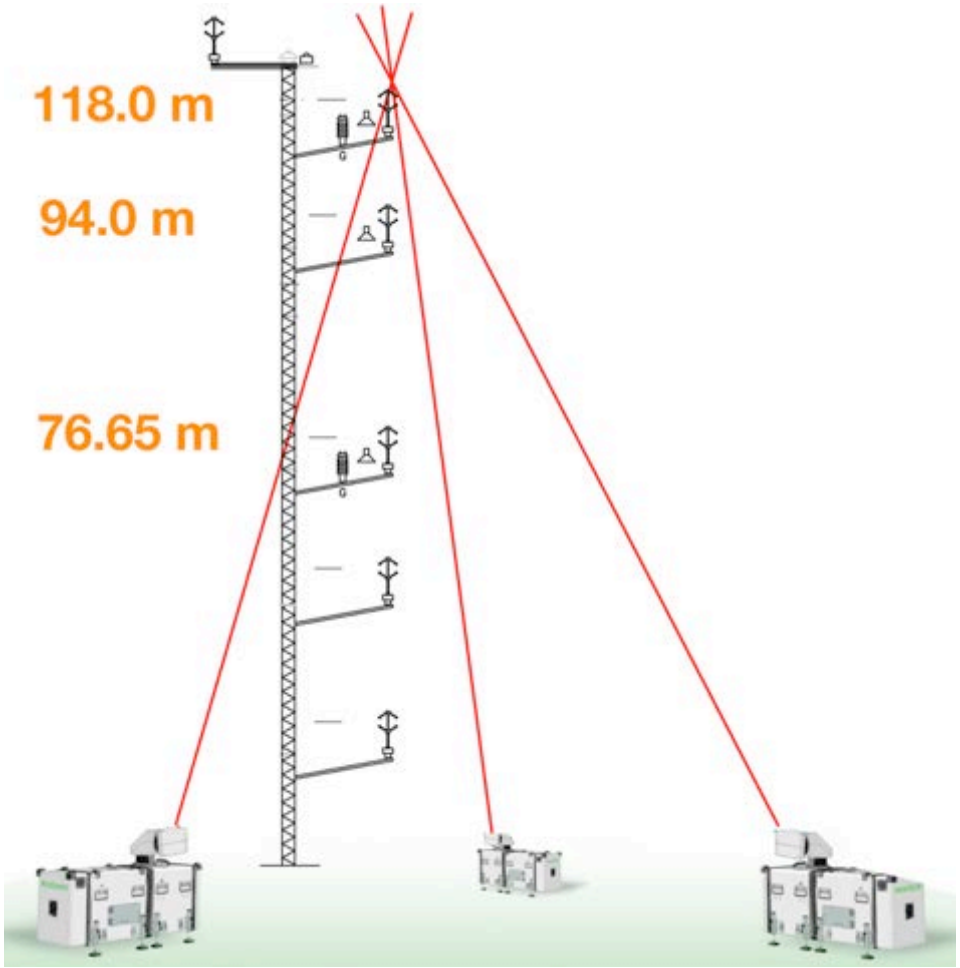
WINDSCANNER OVERVIEW

Long range Wind Scanners synchronously operating to measure wind speeds

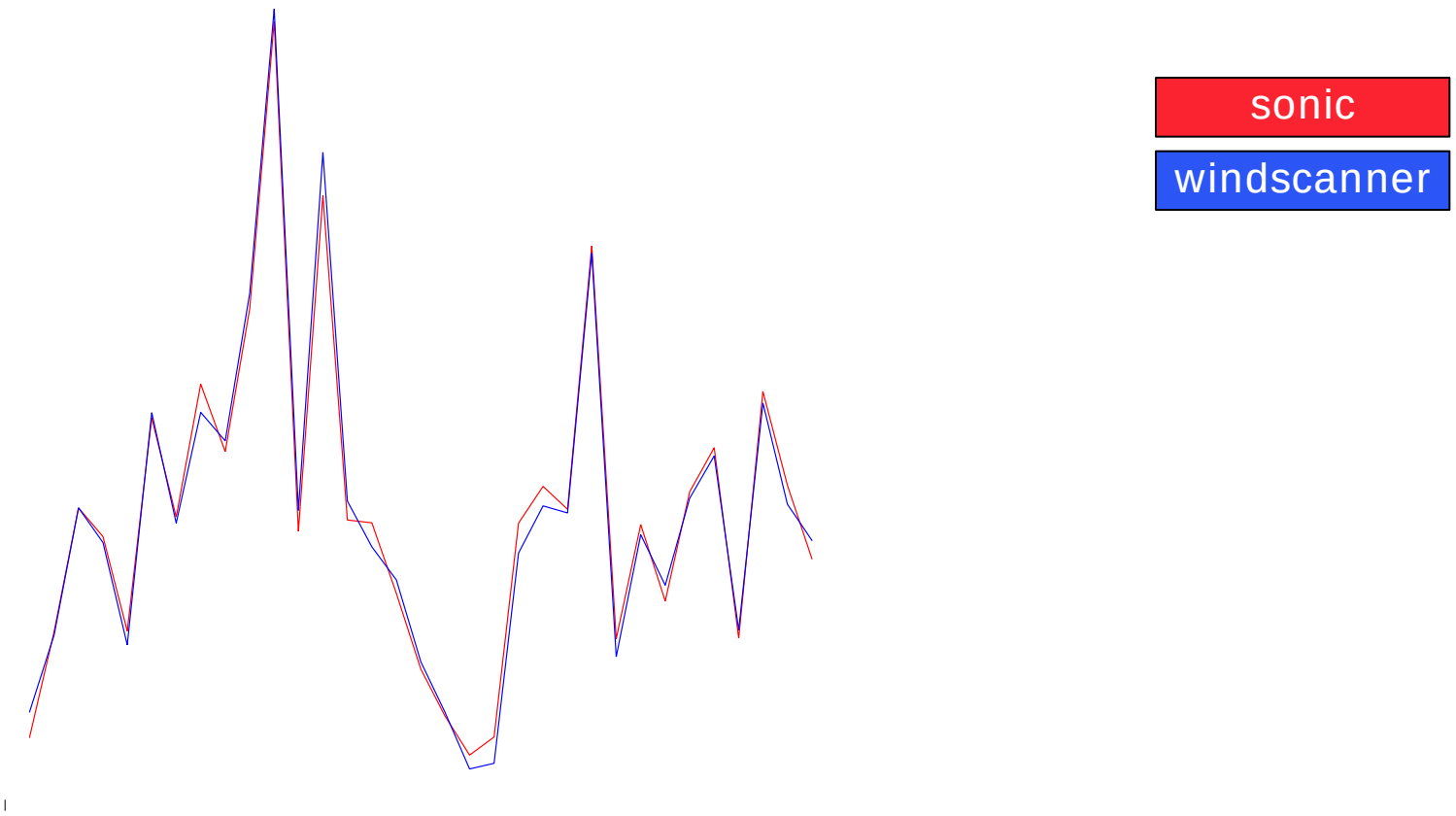

WINDCUBE 200S

Measurement scenario 1 - LOS

- Intersecting 3 beams at 118m
- Sampling rate 1 Hz
- Pulse length: 200 and 400 ns
- Around 20 hours of collected data



Sonic on Sterenn LOS



Long pulses, 10 min mean, 6 hours of data

WindScanner.dk (2007 -)

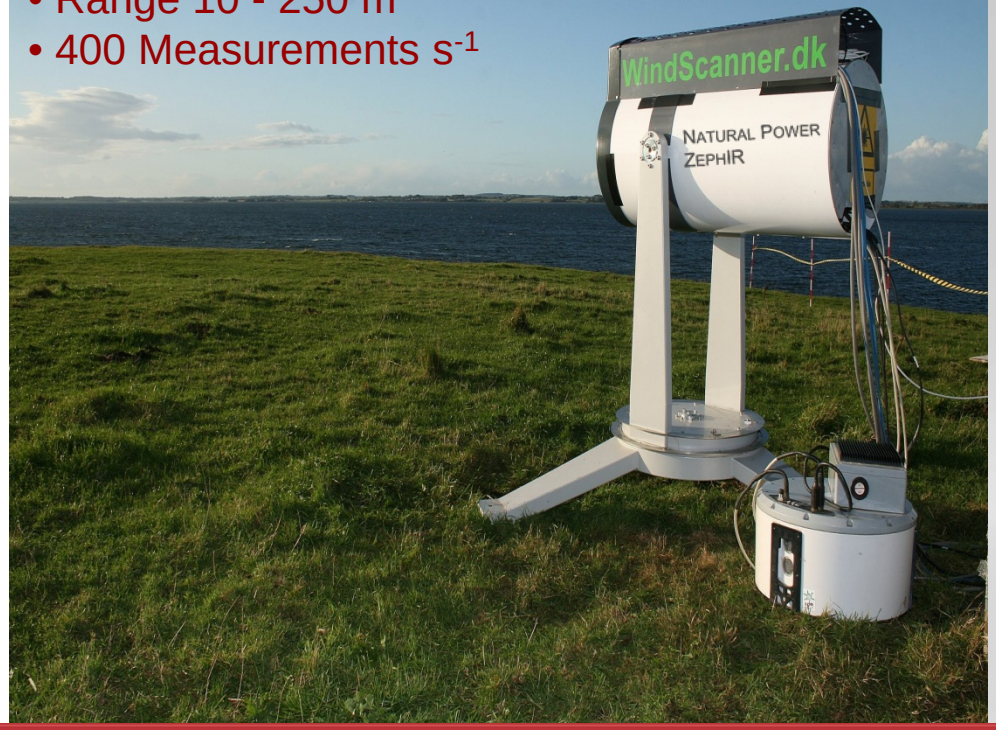
A new Remote Sensing based Research Infrastructure Facility

Torben Mikkelsen, Mike Courtney, Jakob Mann; Søren Knudsen; Mikael Sjöholm; Nikolas Angelou;
Kasper Hjort Hansen; Nikola Vasiljevic; Farzad Abari Foroughi; Per Hansen

tomi@dtu.dk

Short-Range WindScanner (3 ps)

- 3D Wind and Turbulence
- Range 10 - 250 m
- 400 Measurements s^{-1}



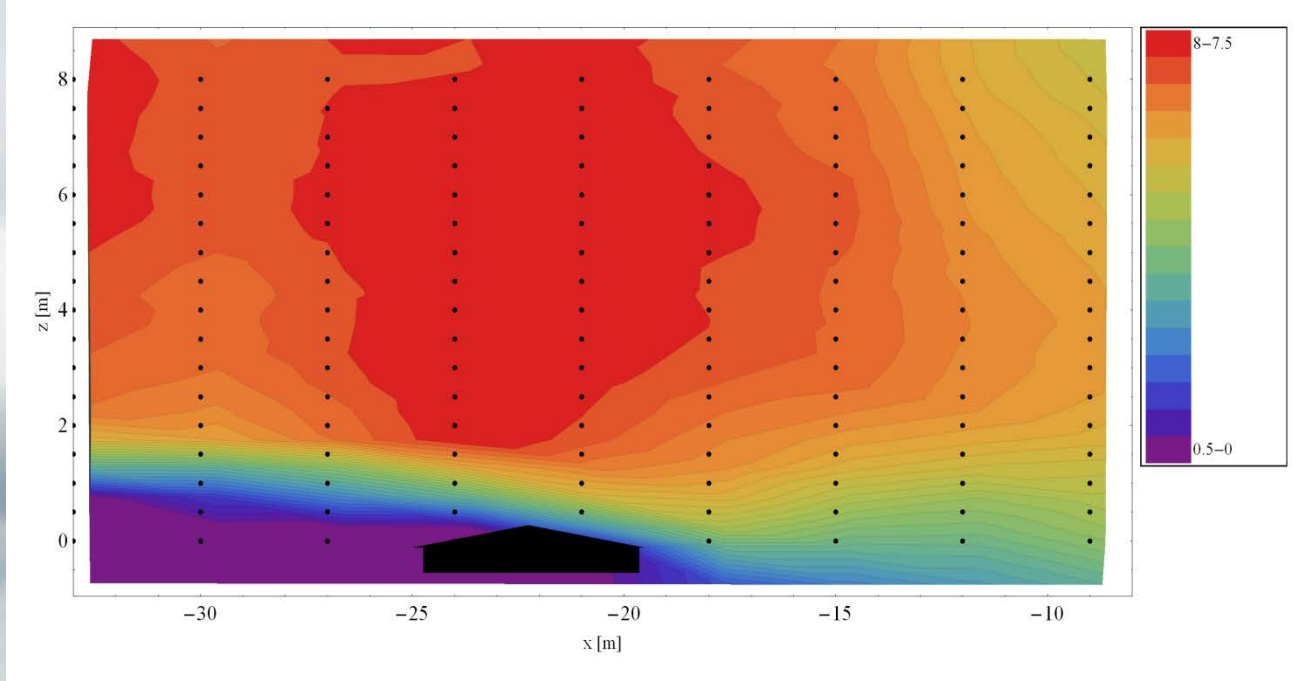
Long-Range WindScanner (3 ps)

- 3D Wind Vector Scanning
- Range 0.1 – 7 km

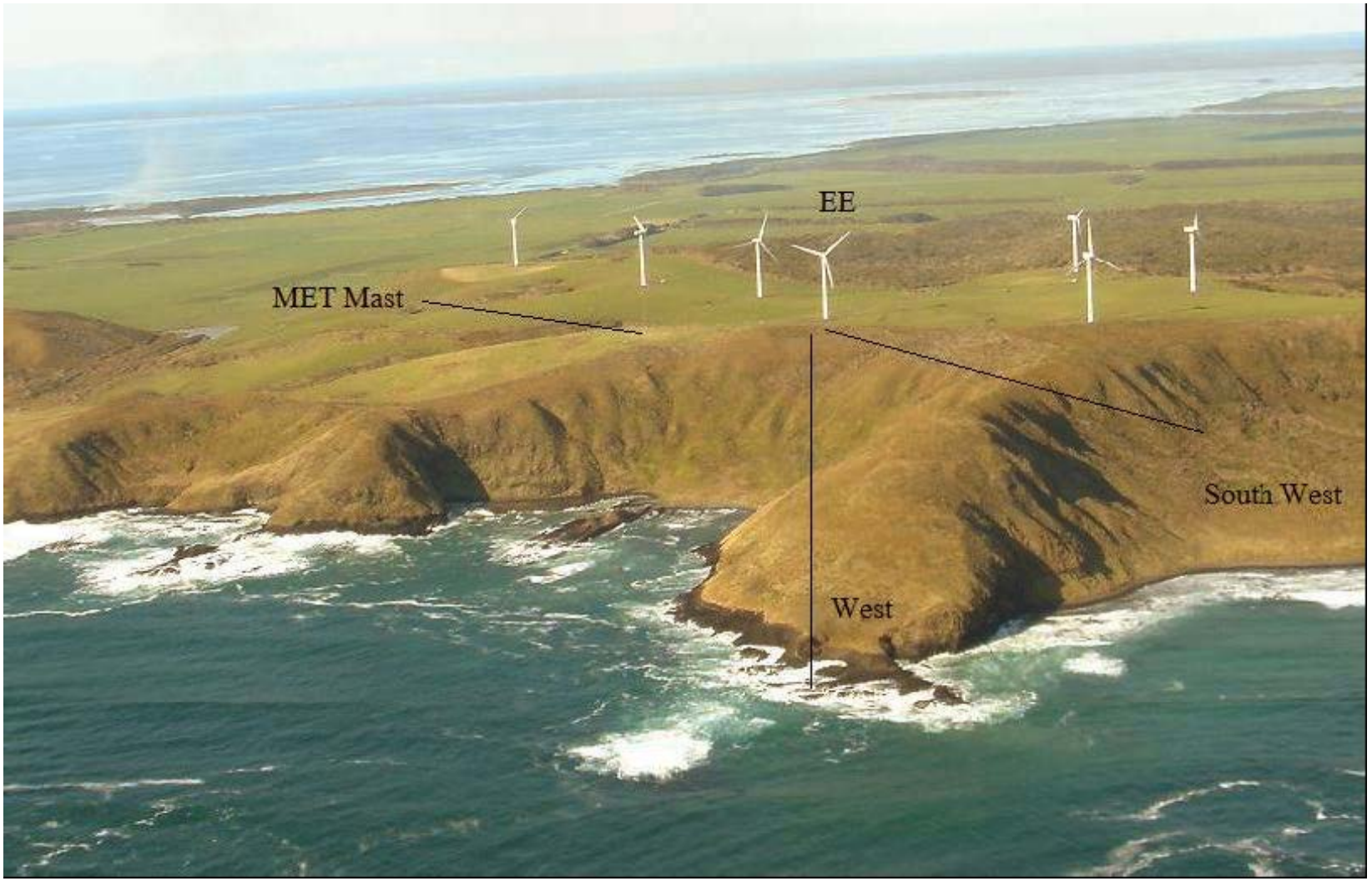
DTU Wind Energy
Department of Wind Energy

Risø Campus
Frederiksborgvej 399, P.O. Box 49, Build. 118
DK-4000 Roskilde, Denmark
www.vindenergi.dtu.dk

Rapid 2D scanning of the flow behind a building



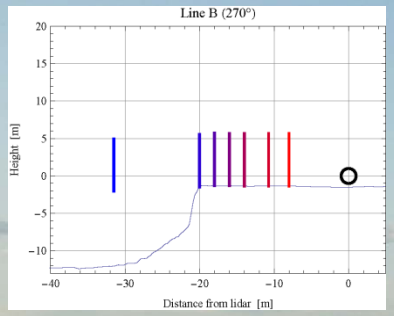
Detailed Resource and Wind Condition Assessment require full-scale 3D flow and turbulence measurements…:

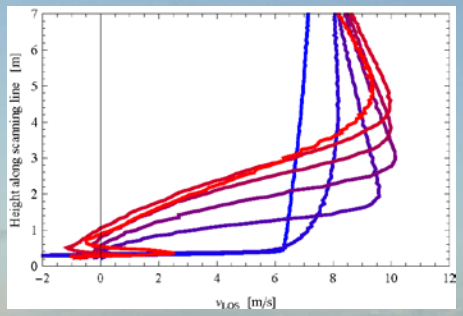


Short-Range WindScanner R2D1:

Scanning inflow over Bolund Hill Oct.2011

Vertical speed profiles at the Bolund escarpment measured by a continuous wave short-range DTU WindScanner



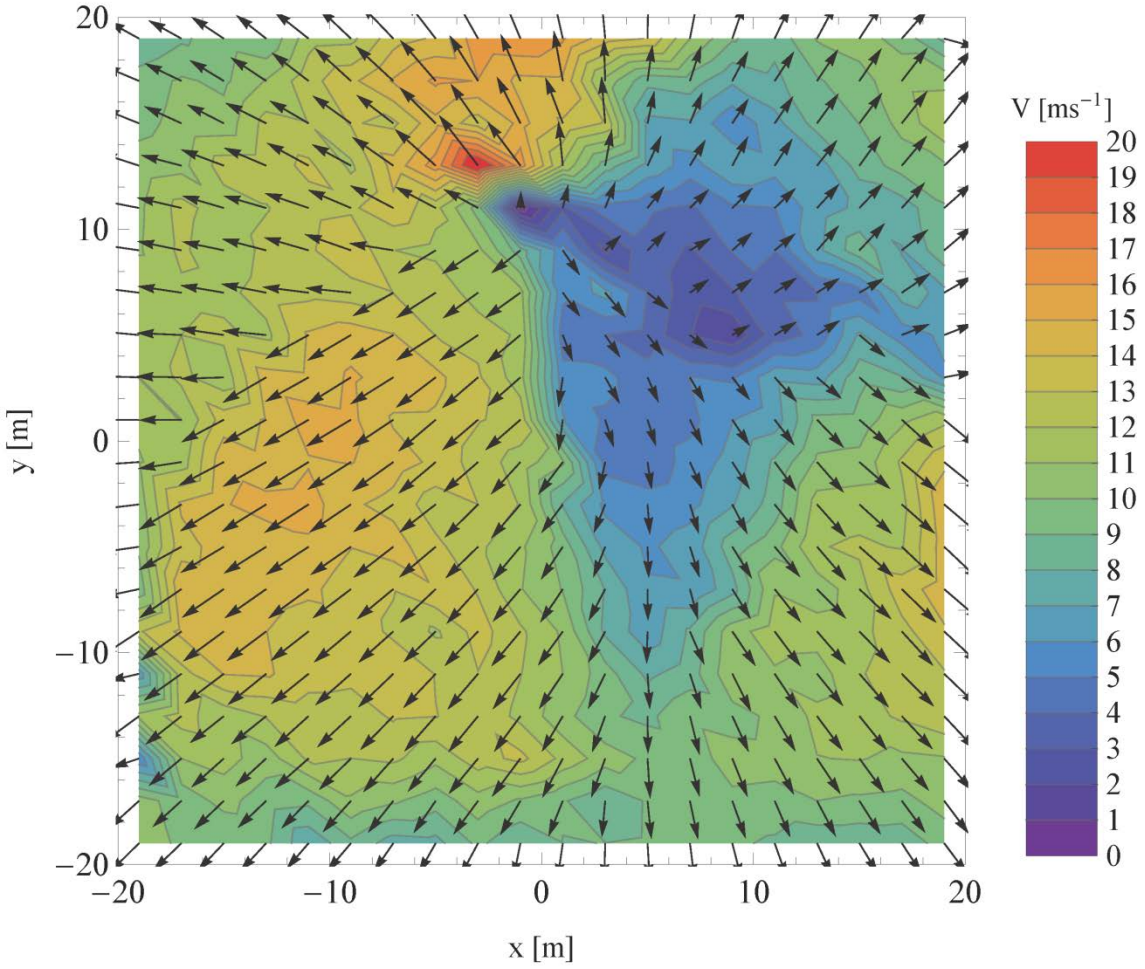


WindScanner.dk

Norwegian offshore rescue helicopter (Sea King 20 ton)

Horizontal scanning Pre-trial :2011-12-06

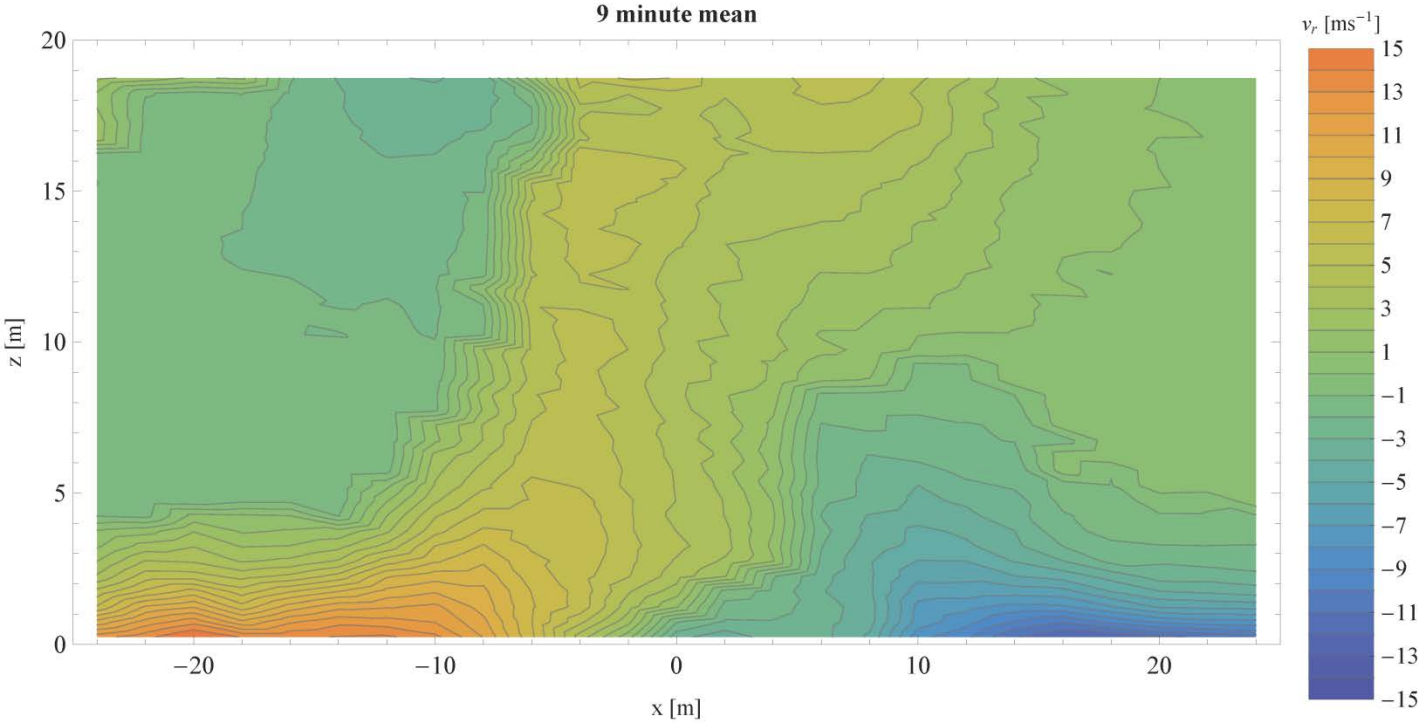
5 MINUTES AVERAGE
Resulting Wind Vector Plot:



Vertical scanning
R2D1 & R2D2: Time 16:50-17:00 2011-12-07

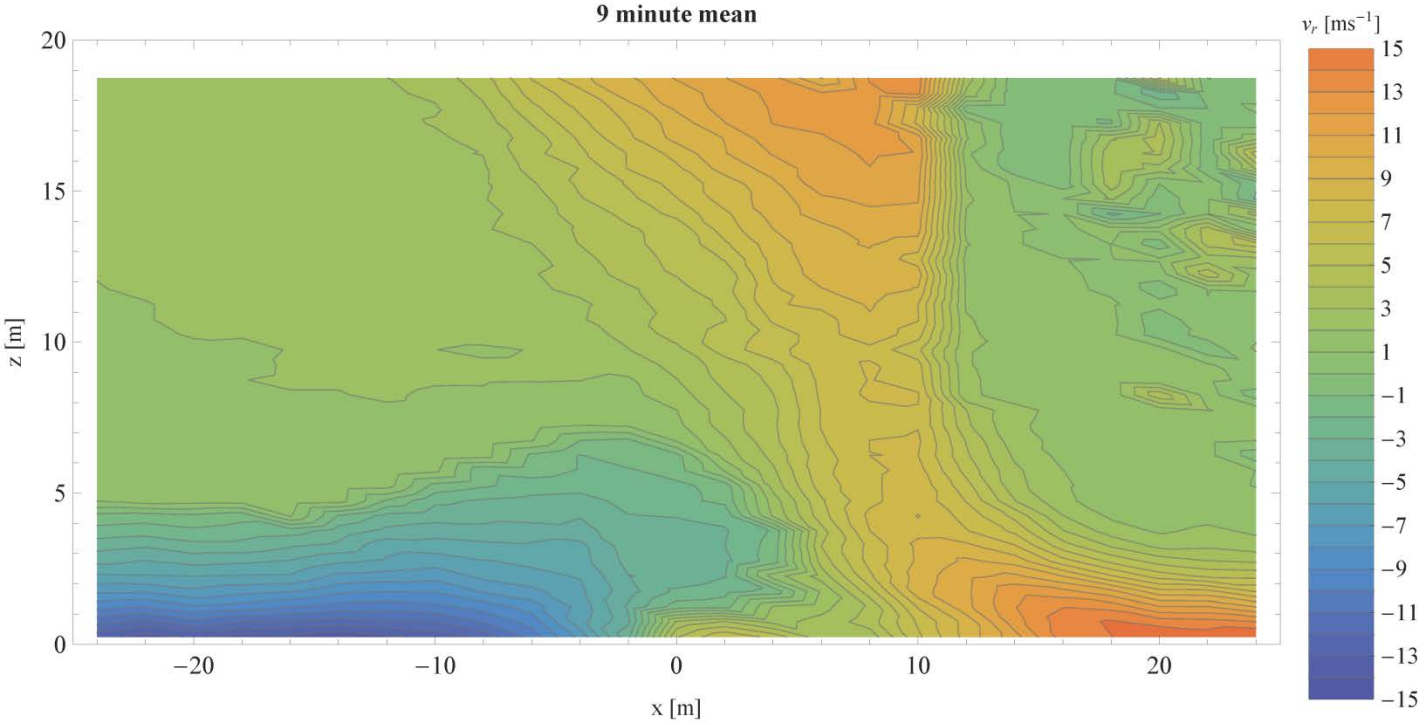
Vertical Scan (9 minute average)

R2D1



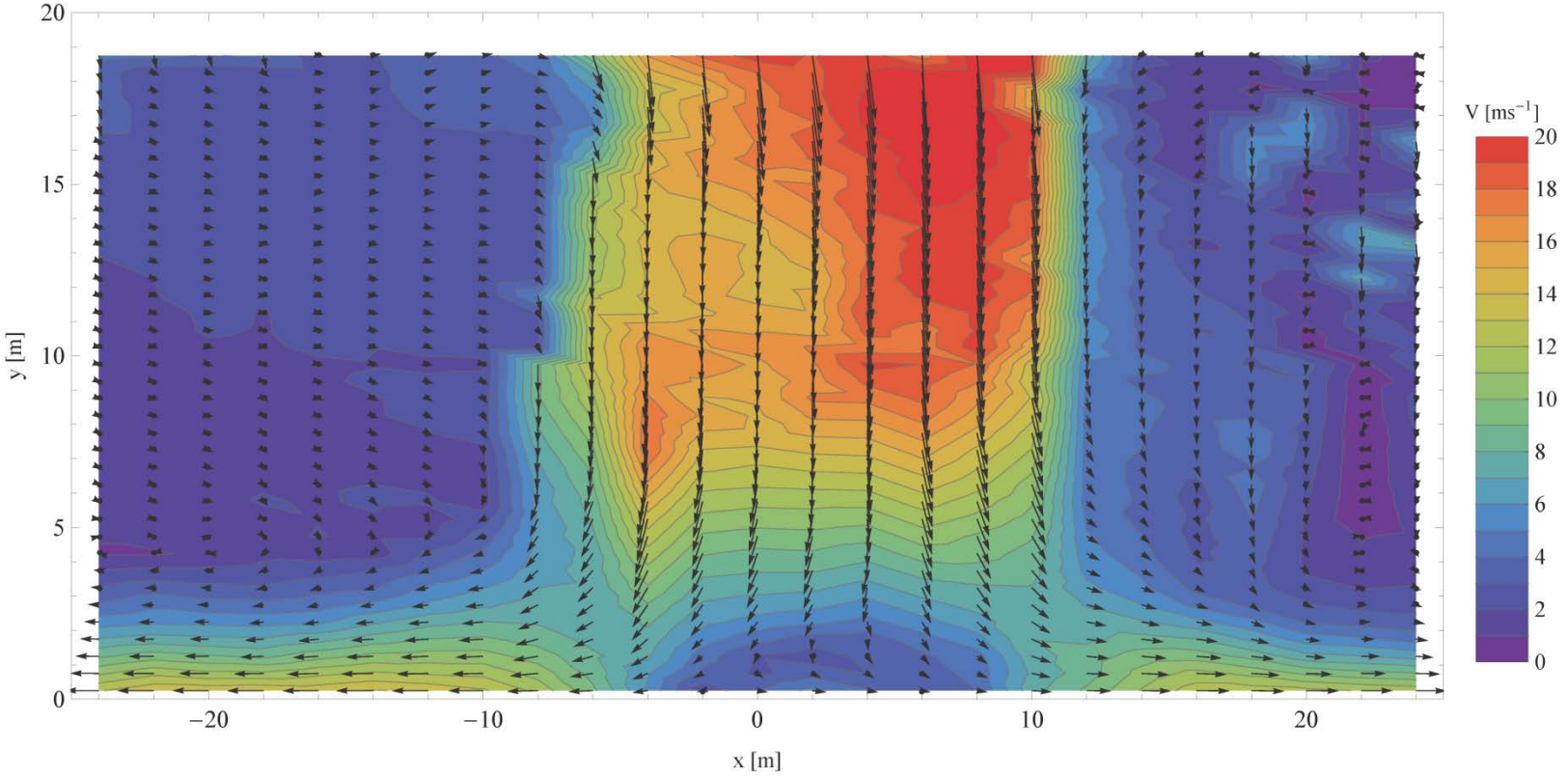
Vertical Scan (9 minute average)

R2D2

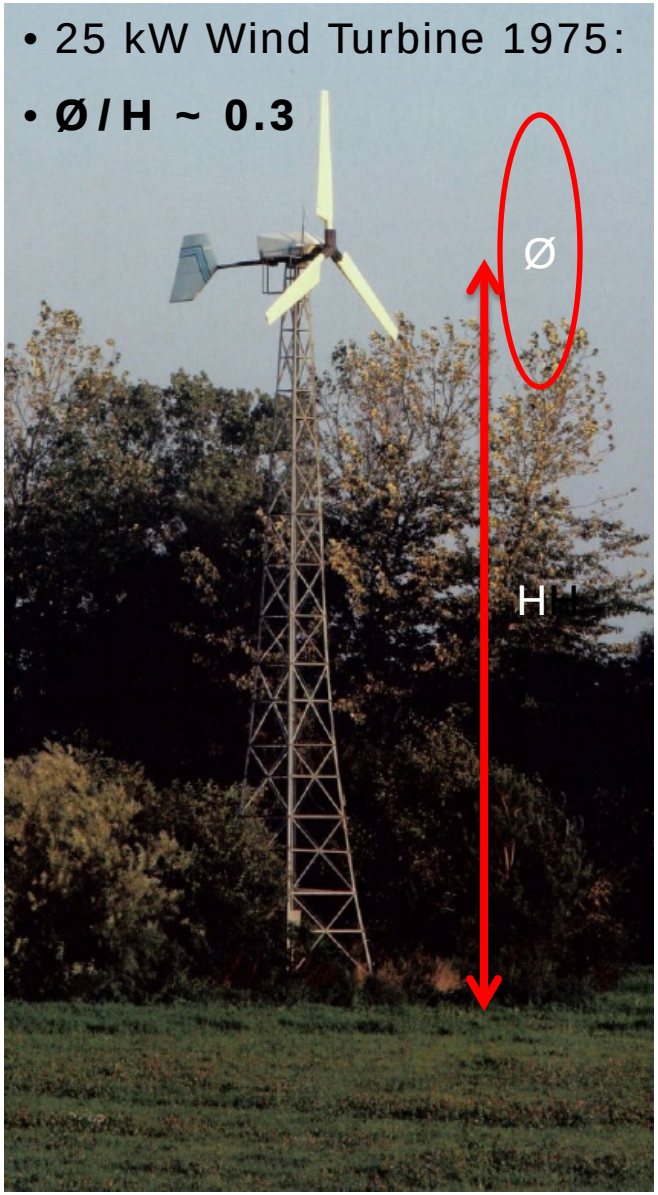


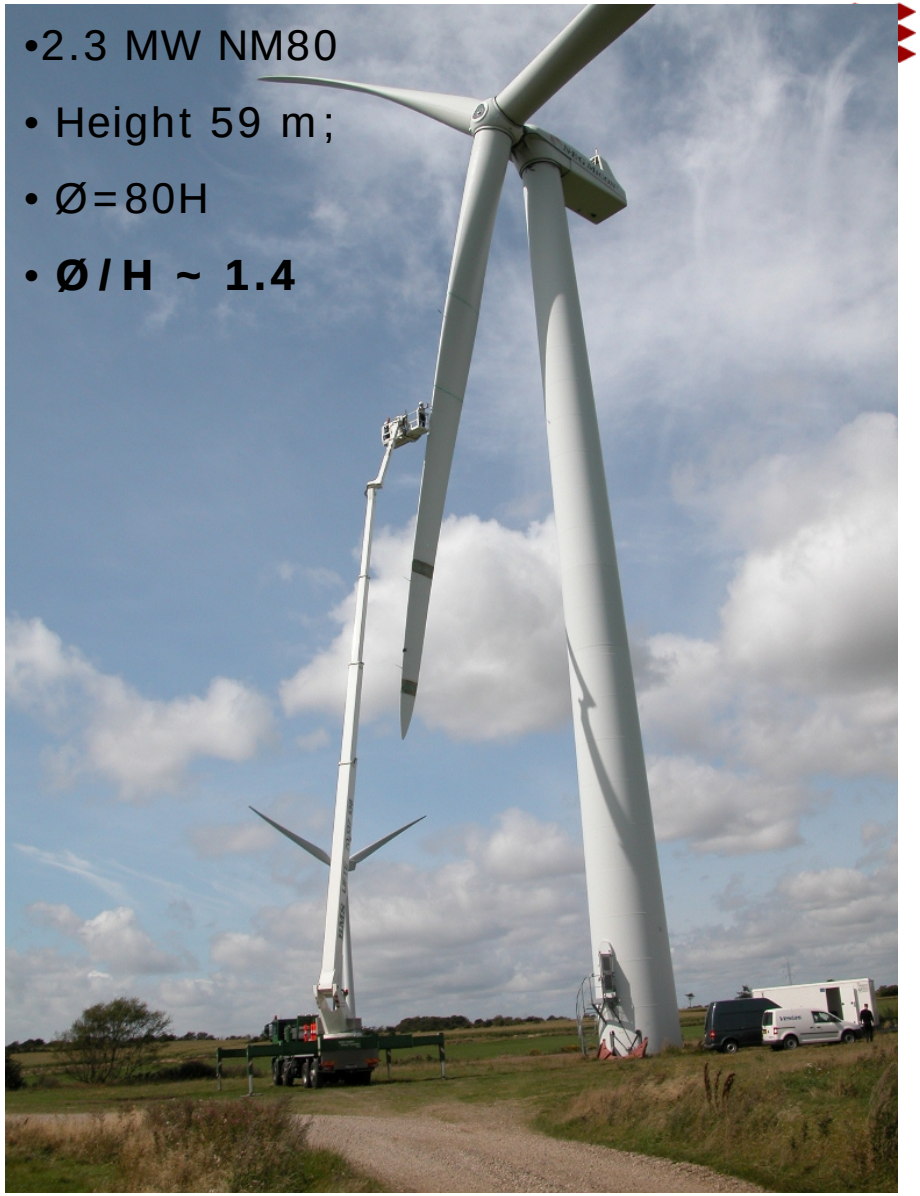
Vertical Scan (10 minute average):

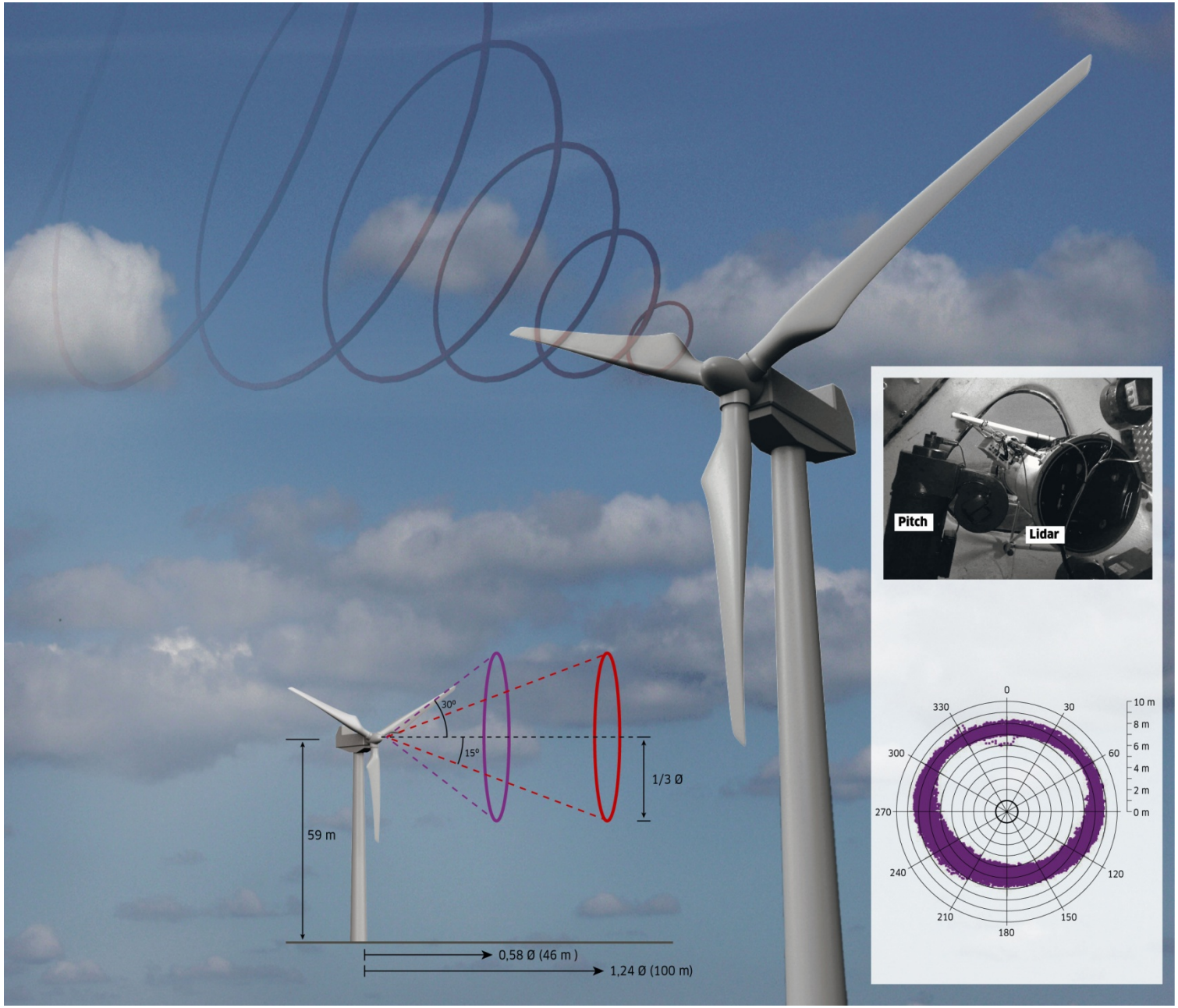
R2D1 and R2D2 vertical scans – Combined to final 2D vertical plot:



Turbine control….:

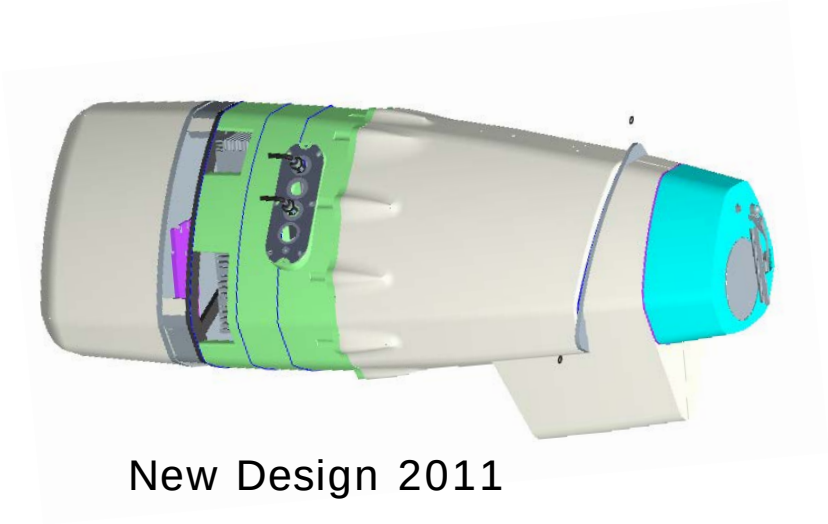

• 25 kW Wind Turbine 1975:
• Ø / H ~ 0.3
Ø
H


•2.3 MW NM80
• Height 59 m;
• Ø=80H
• Ø / H ~ 1.4

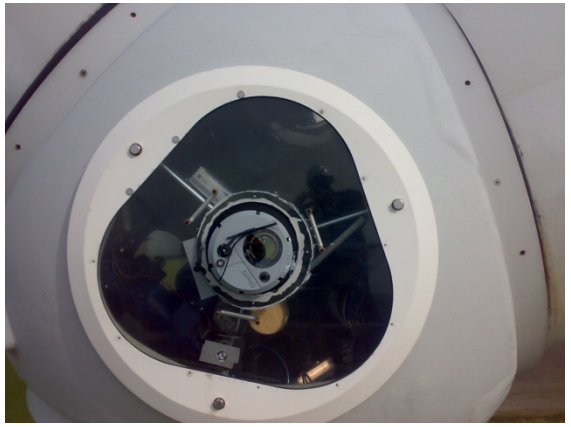

Pitch
Lidar
30°
15°
1/3 Ø
59 m
0,58 Ø (46 m)
1,24 Ø (100 m)
0
30
60
120
150
180
210
240
270
300
330
10 m
8 m
6 m
4 m
2 m
0 m

Design concepts for “**HTF Spinner Lidar**”:

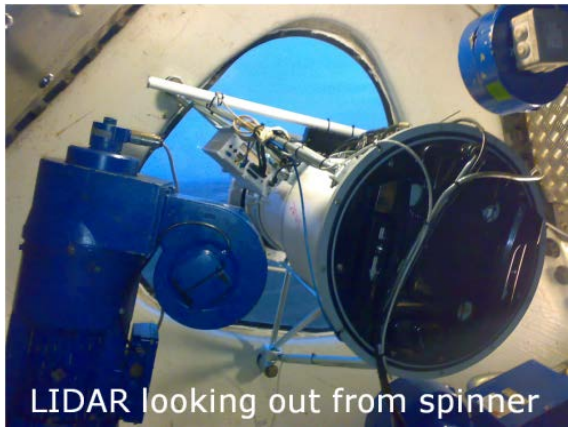
ControlZephIR Lidar equipped with 2D Scan Head



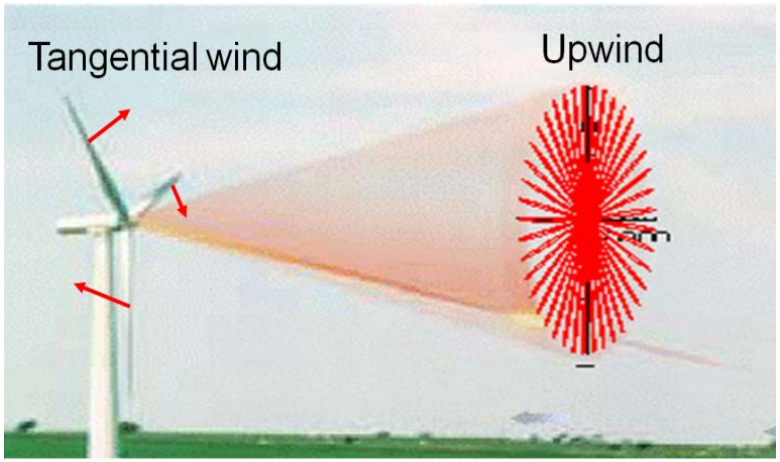
New Design 2011



Lidar in Spinner Tjæreborg 2009

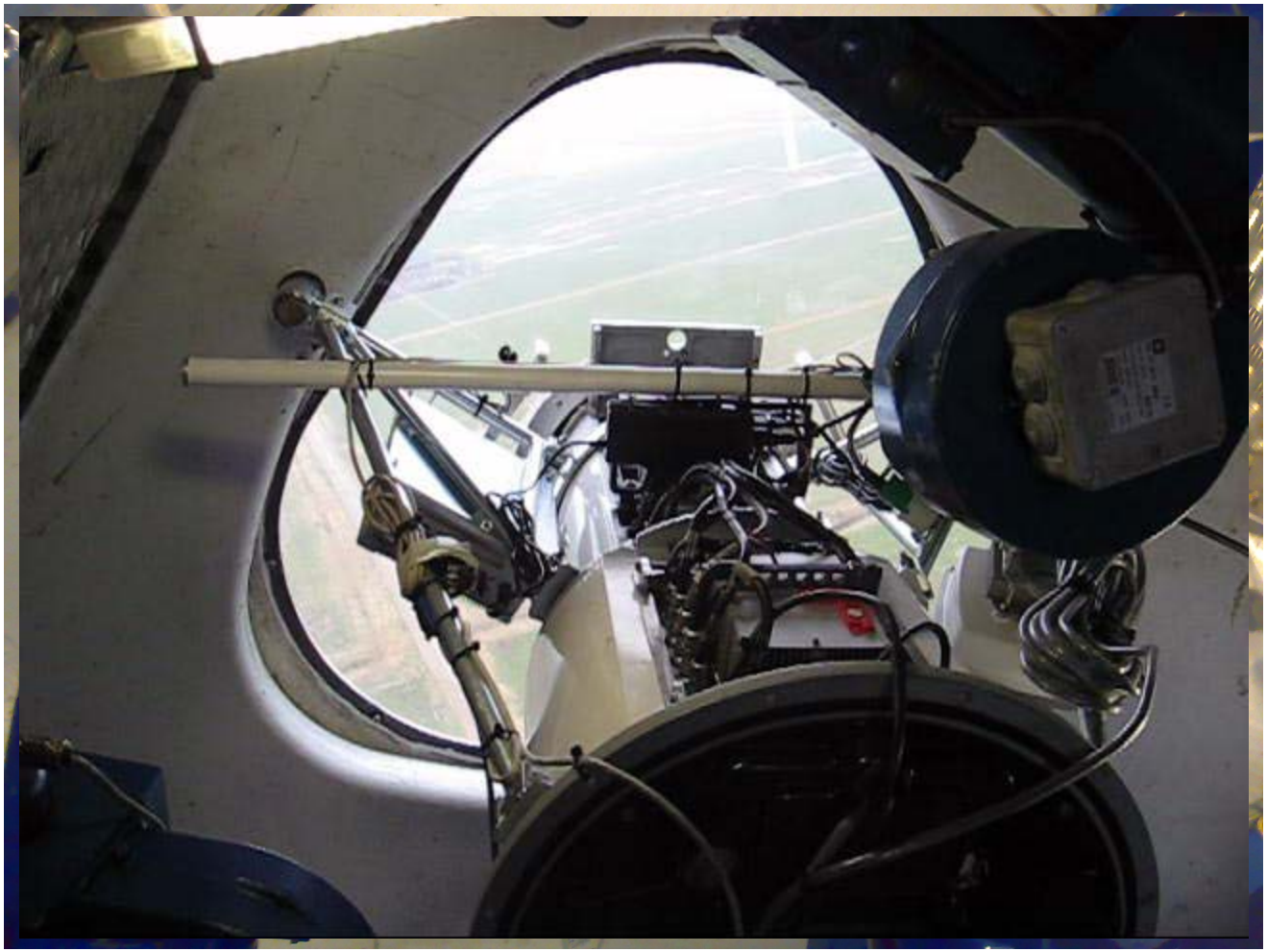


Prototype test 2009

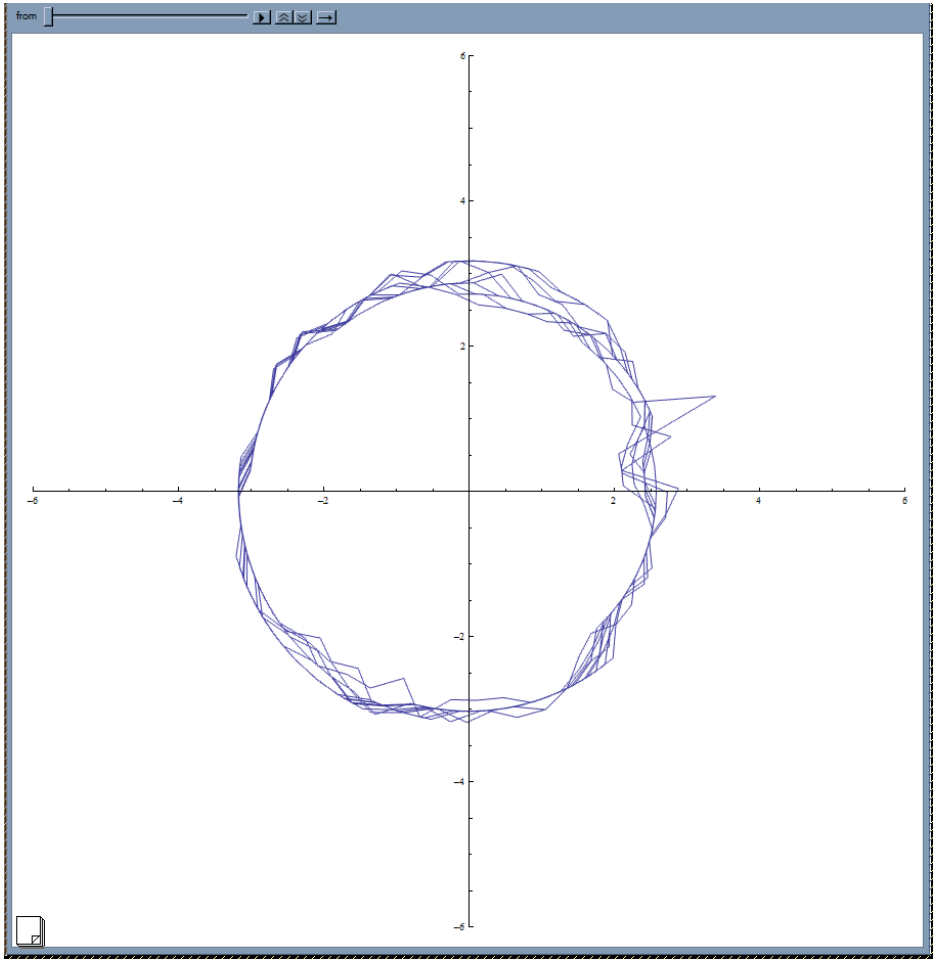


2D Upwind scanning concept

Tjæreborg NM80 2009

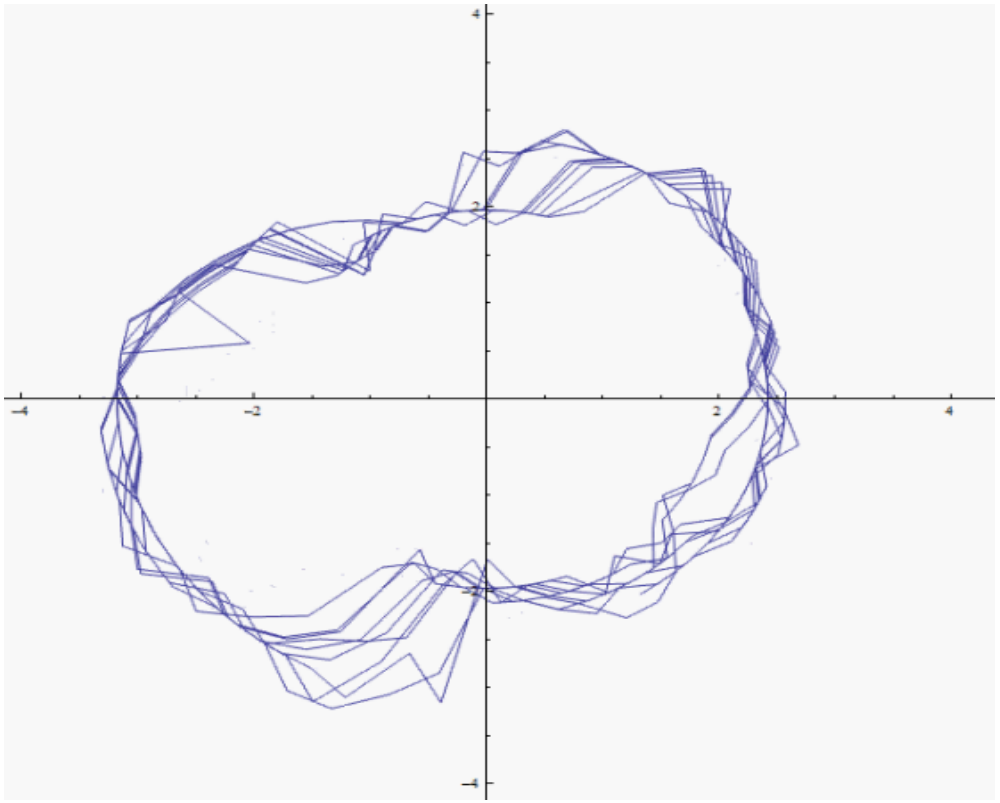


Real-time LIDAR Raw data (50 Hz un-calibrated):



Time series (10 s) of approaching wind conditions measured +100 m upwind:

Ex.: Inhomogeneous wind field



Lidars: More Power ?

Power Curve with Anticipatory Collective Pitch

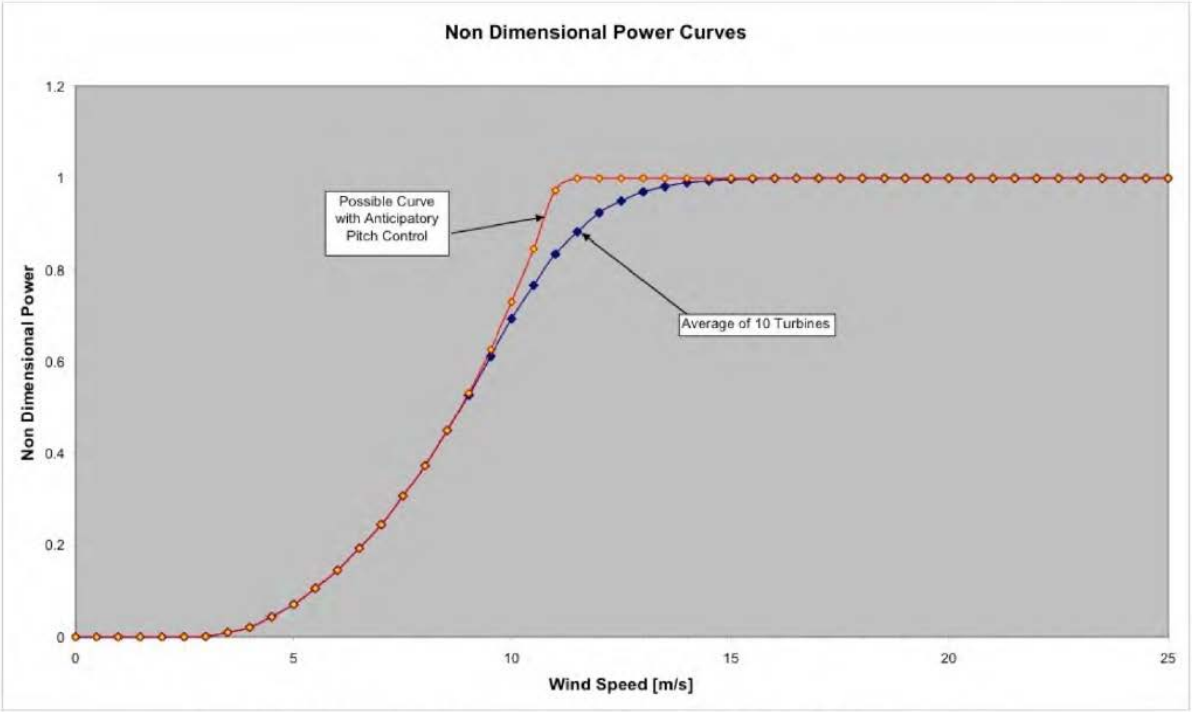


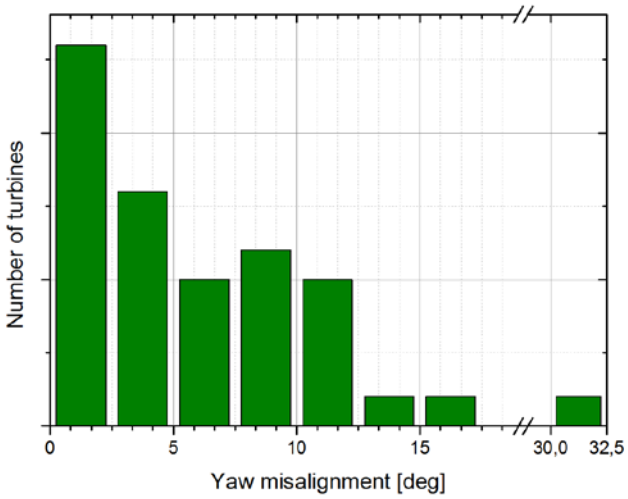
Figure 2. Representative Average and Modified Power Curves

Courtesy of H. Drees

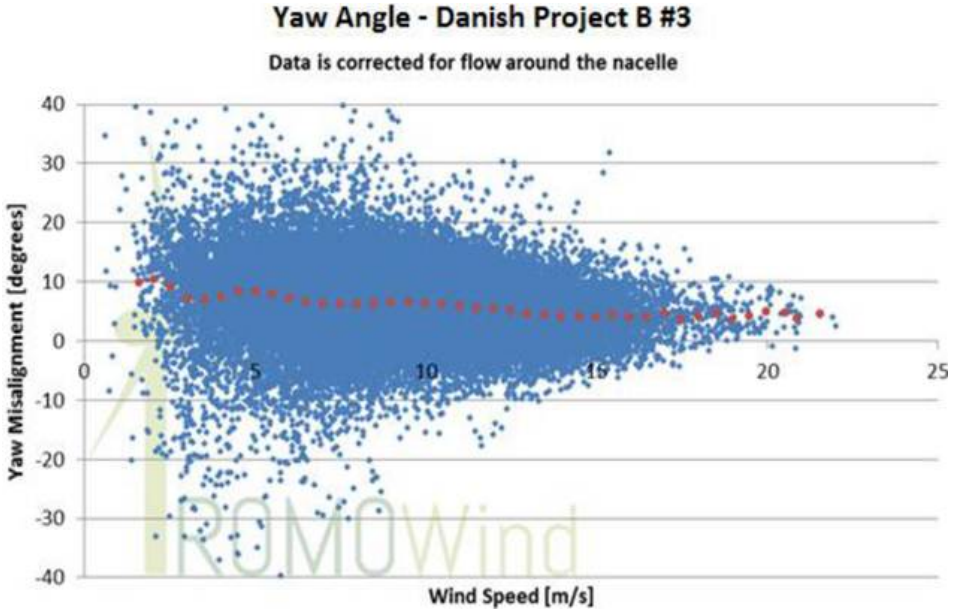
Lidars: Reduce Yaw Error?

Measurements of Yaw Error Statistics (ROMO):

Højstrup, J., EWEA 2013: Poster viser middel krøjefejl for 40 møller. Den dynamiske krøjefejl varierer meget fra mølle til mølle til mølle. Figuren til højre viser iflg. JH en tilfældig (typisk) mølle [50 sec middelværdier].

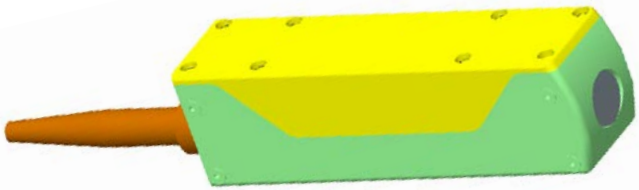


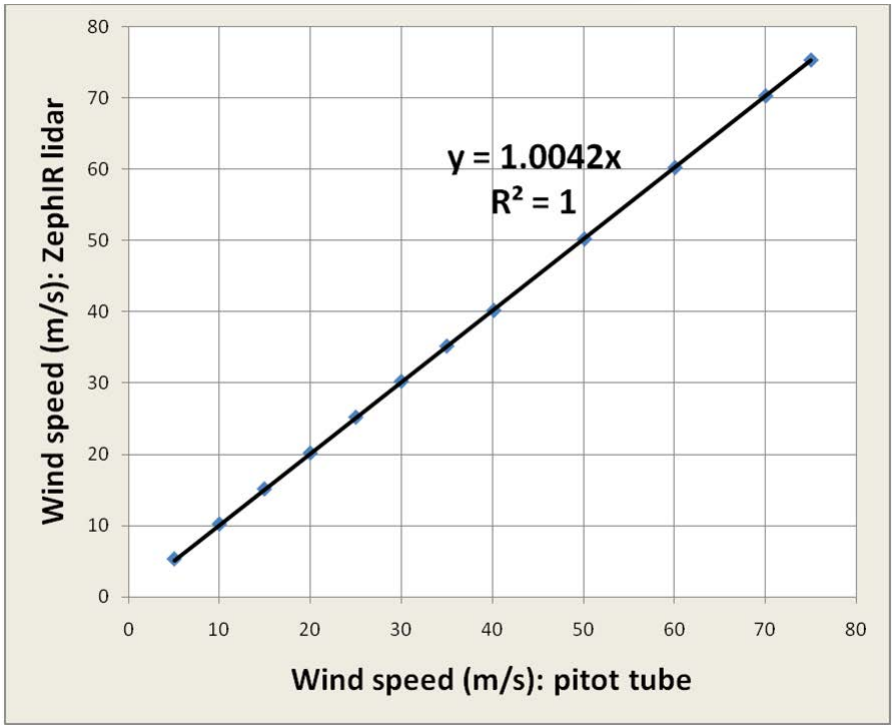
Yaw Error Misalignment (40 turbines)



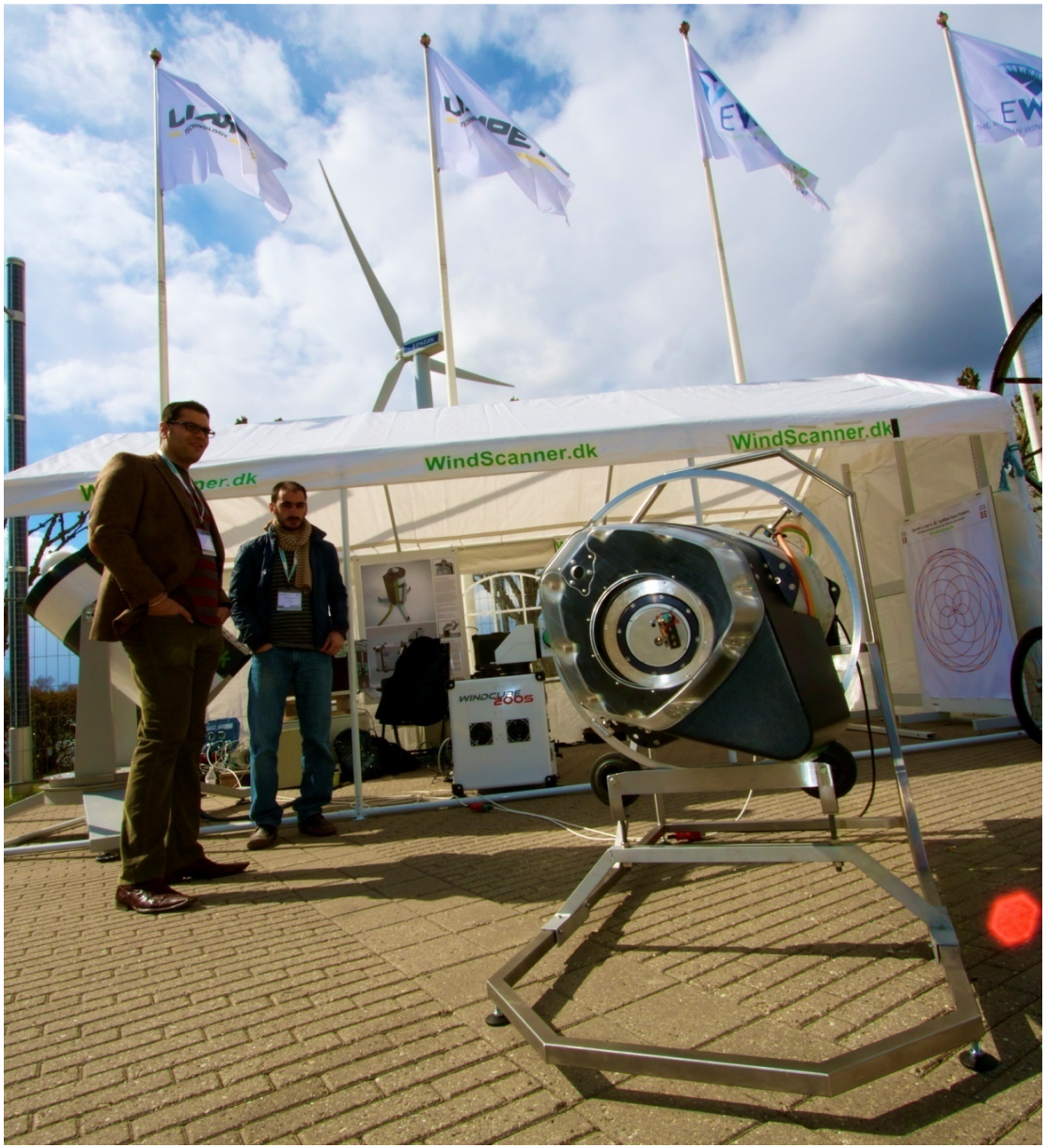
Typical Turbine (50 s averages)

Wind Tunnel Test of **LIDIC'S**



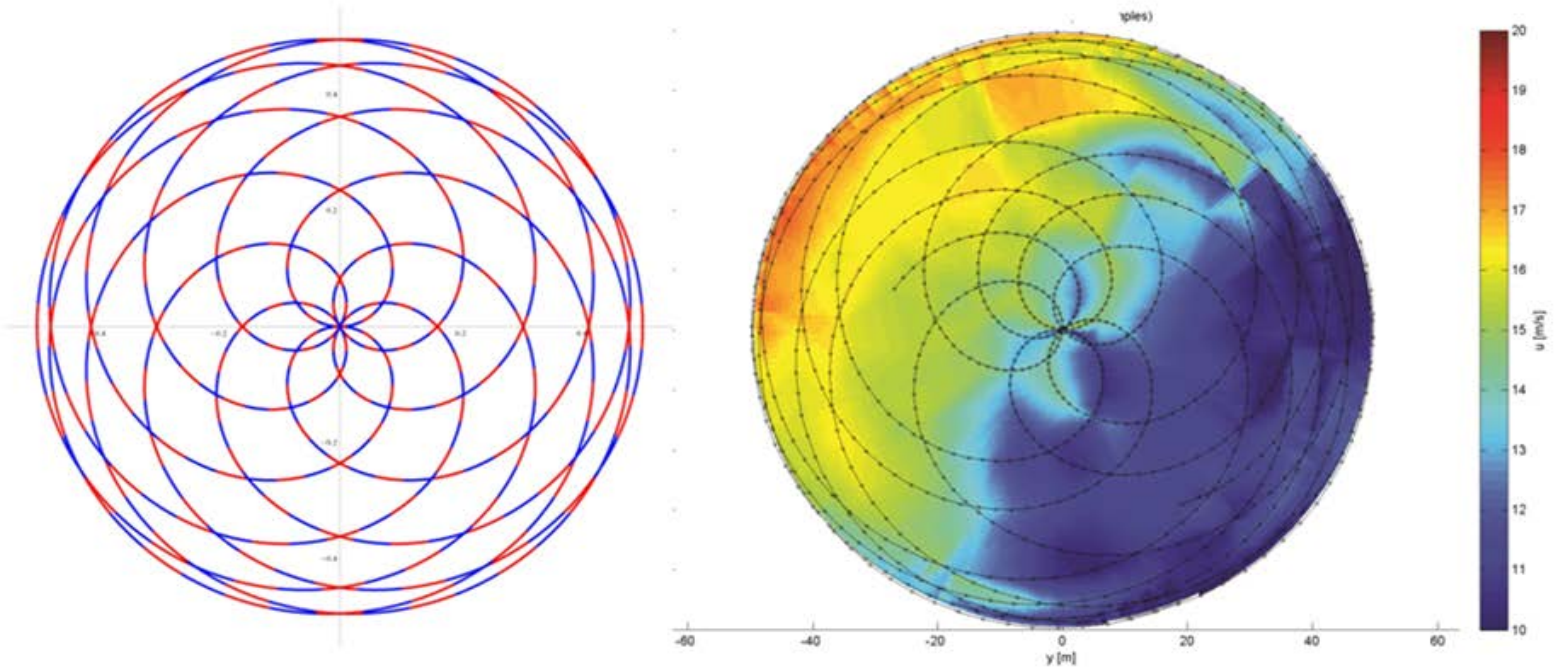


Presenting the 2D “SpinnerLidar” at EWEA 2012 Copenhagen:



Ex.3:
WindScanner (SpinnerLidar) UpWind 2D scanning from the rotating spinner of 2.3 MW NM80.

400 wind speed measurement points are retrieved from the scanned wake every (other) second :

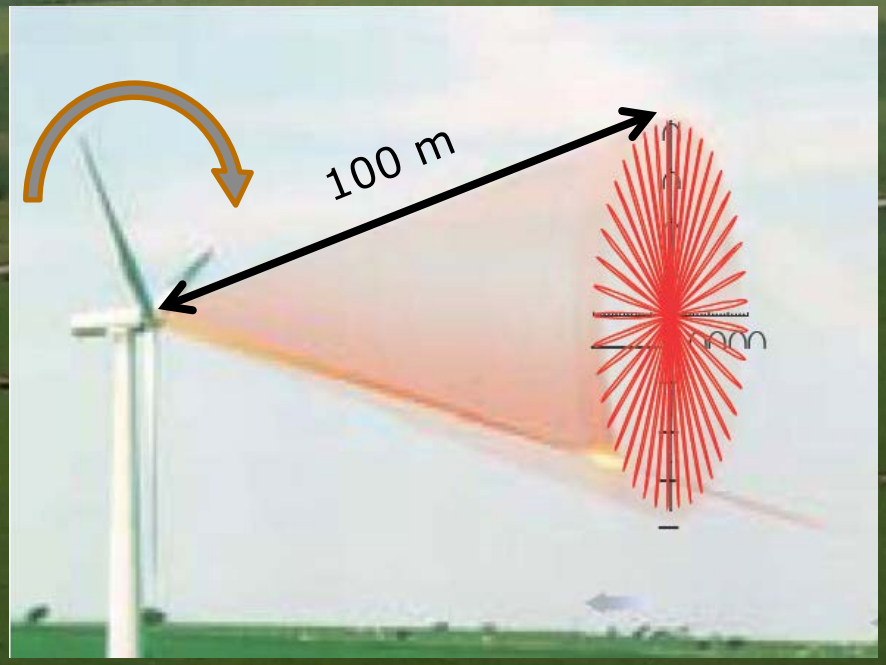


Danish HTF Wind Lidar Integration at Tjæreborg Jul. - Oct. 2012:

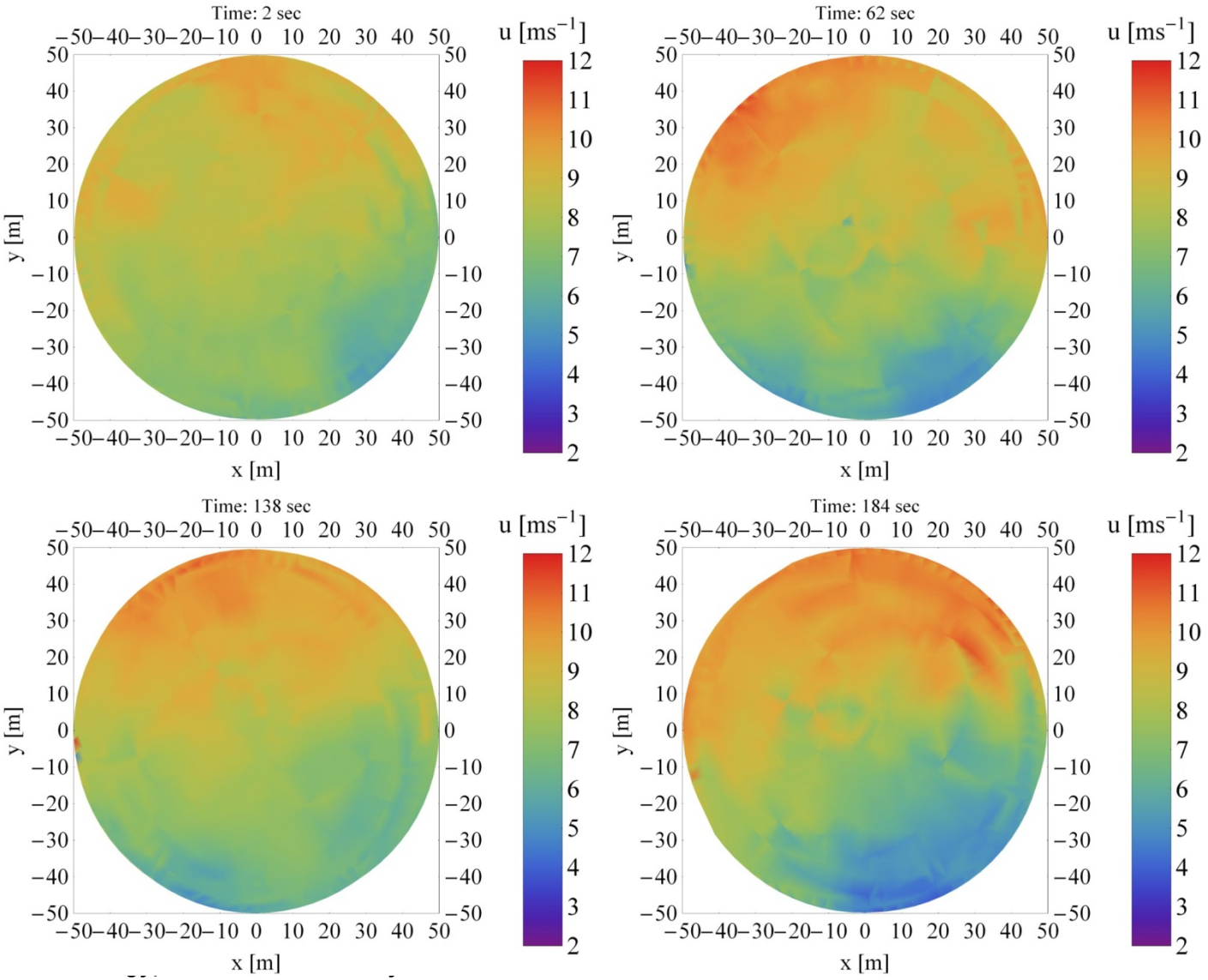
Blade-lidar installation in Blade #1 @ r=18 m NM80 2.3 MW July 2012.

First 2D SpinnerLidar measuring inflow 100 m upwind NM80, 2.3 MW WT:

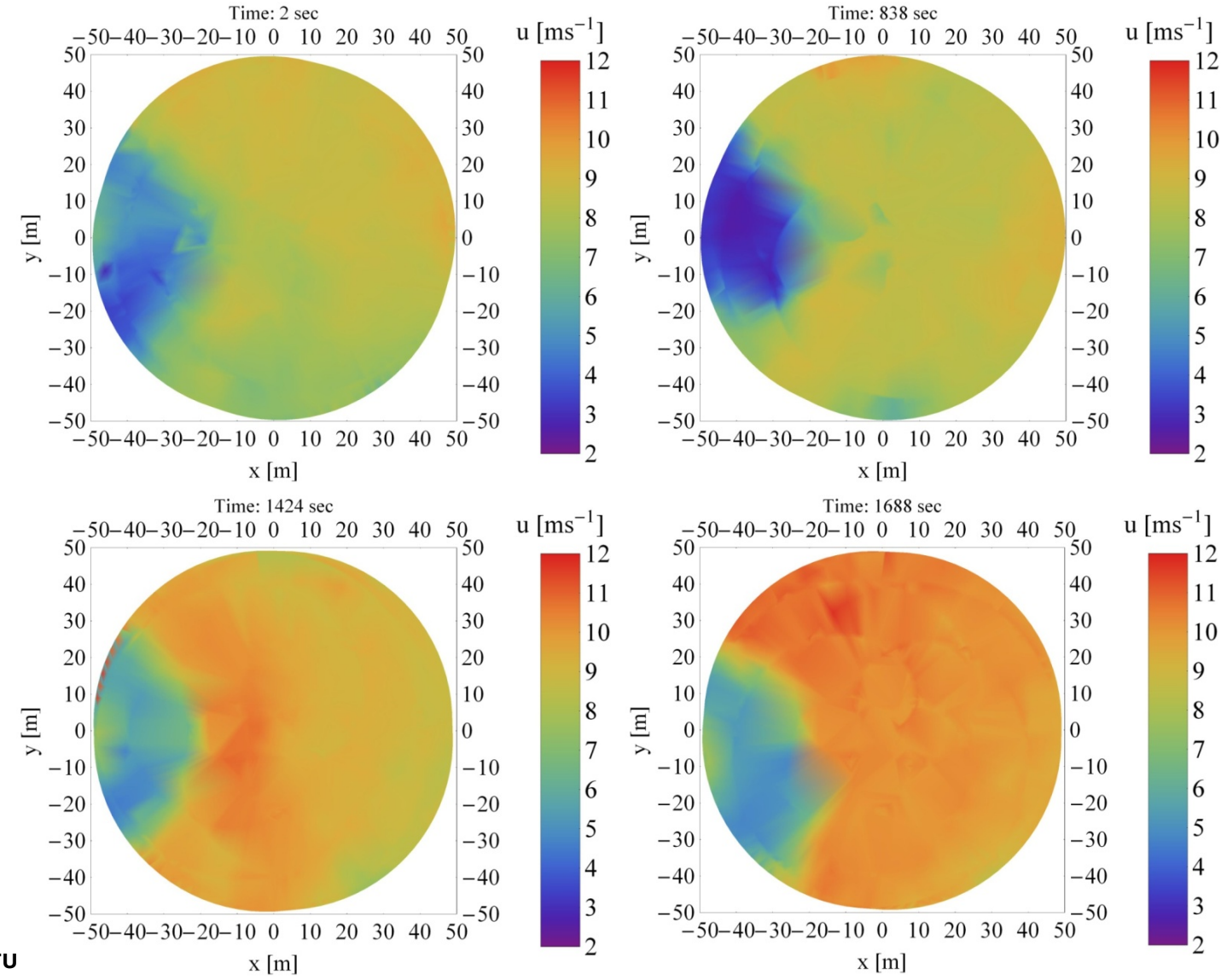
The Tjæreborg set-up



Inflow without wake influence

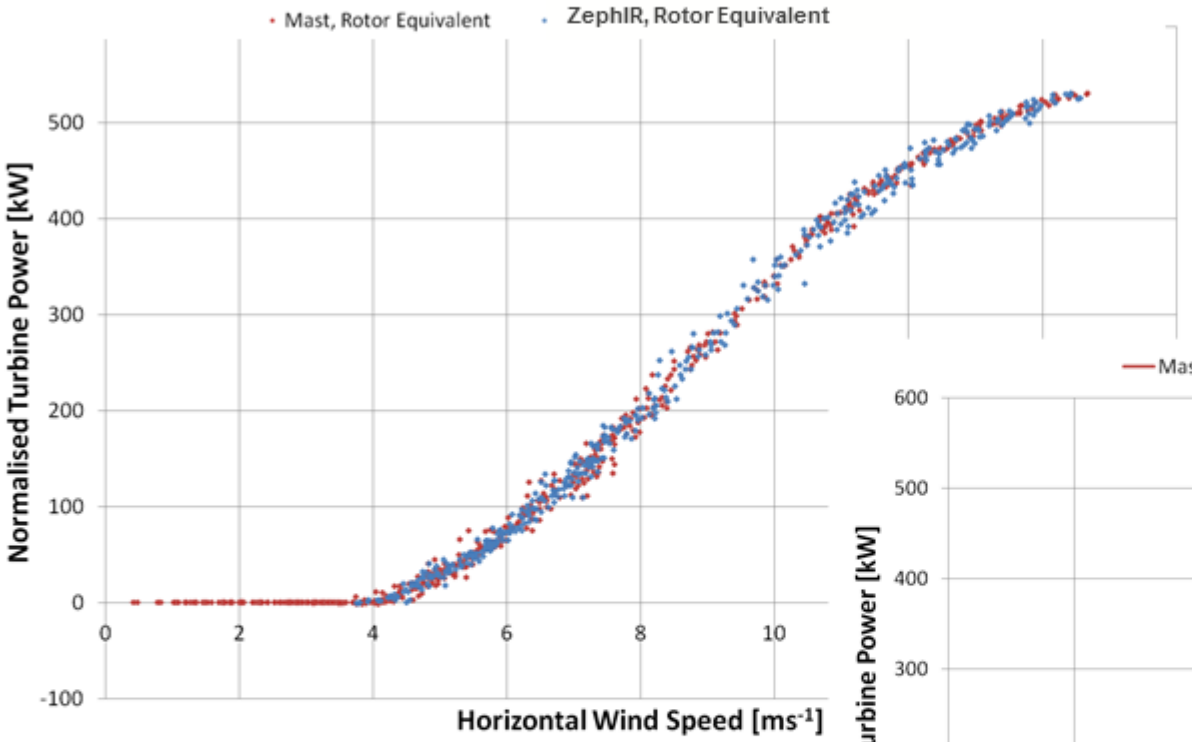


Inflow with wake influence

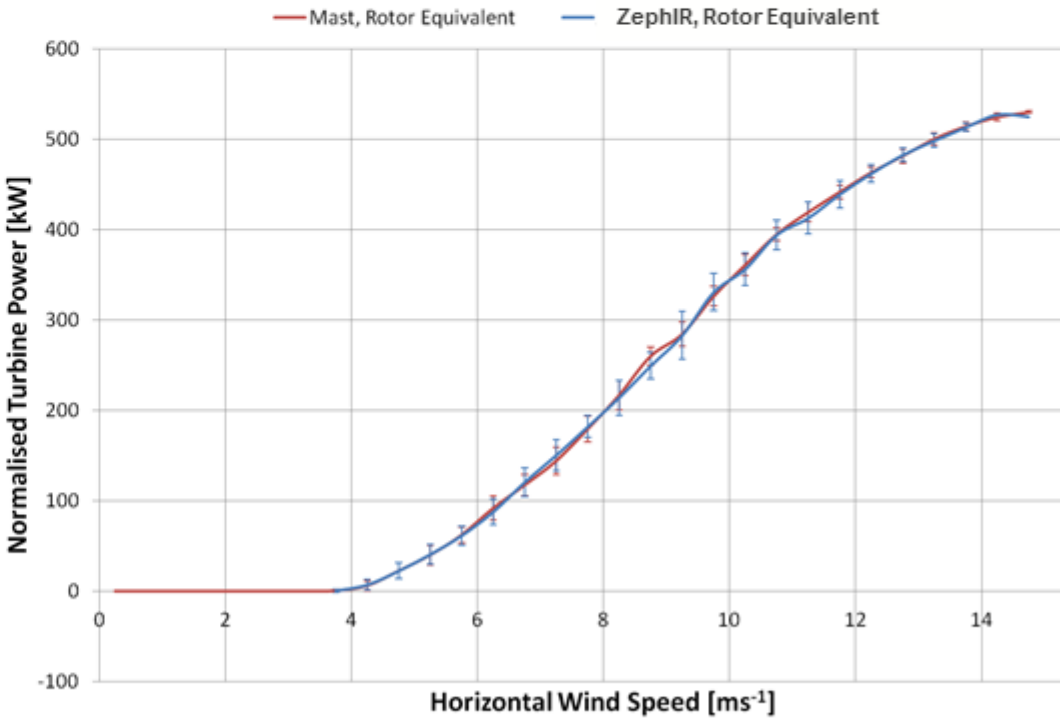


Power Curve measurements with ZephIR Dual Mode Control Lidar @ DTU Risø Campus NKT550 2013:

Power curves based on rotor equivalent quantities



ZephIR RE measurement heights of 27, 36, 45 and 54 m at 90 m measurement range. The rotor equivalent mast speeds were calculated using the cups at 27, 36, 45 and 54 m and the sonic anemometers at 16.5, 34.5 and 53,5 m.



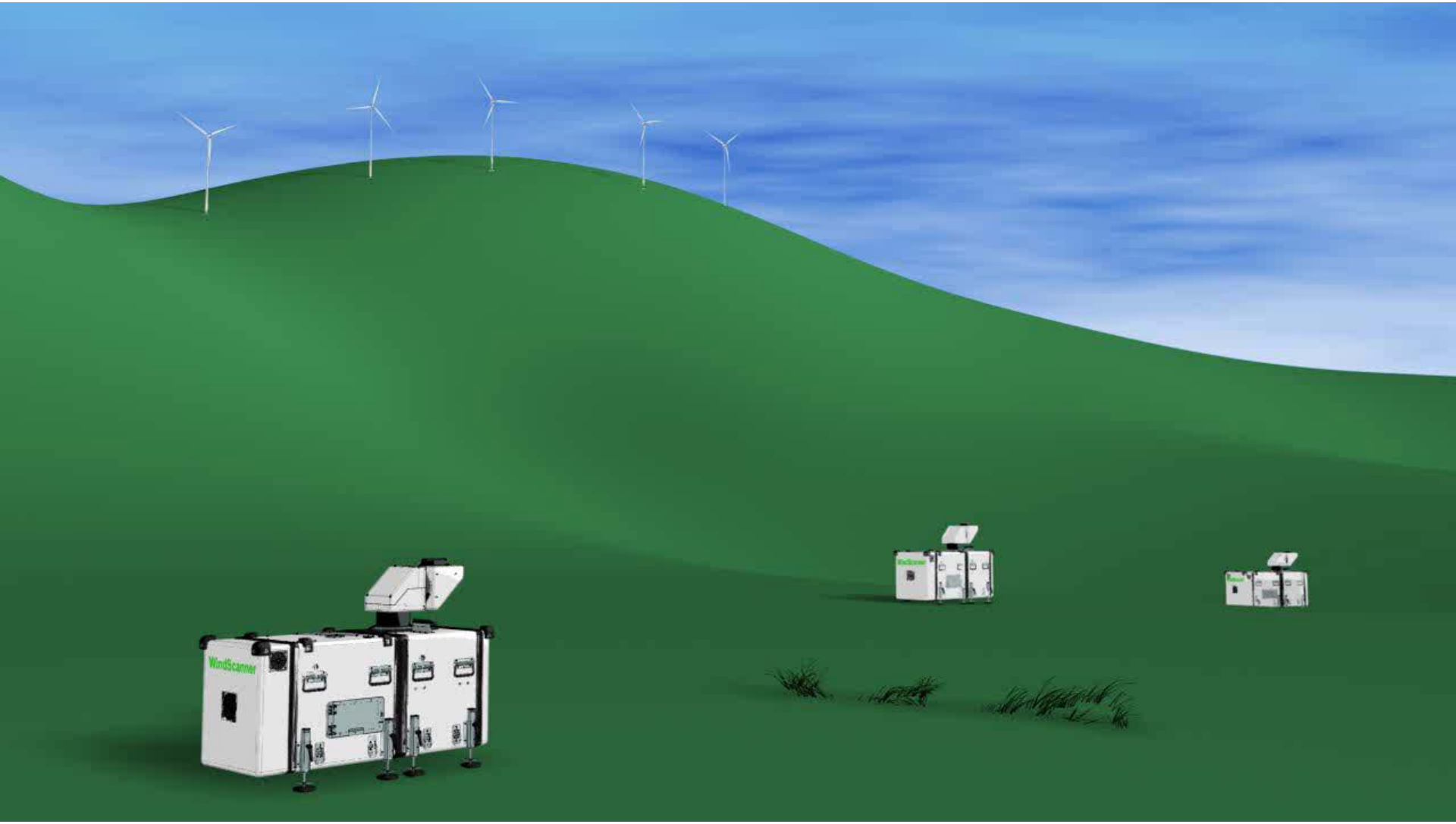
ZephIR Lidar

WindScanner

Short-range:


WindScanner
WindScanner
Long-range

Long-range:



Wind turbine control:


WindScanner
Spinner integrated upwind looking wind lidar


WindScanner
Offshore scanning

Off shore: